



CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY  
REGIONAL WATER QUALITY CONTROL BOARD  
CENTRAL VALLEY REGION

**Clear Lake TMDL for Mercury**  
**Numeric Target Report**

**Staff Report**



*June 2001*

*State of California*  
*California Environmental Protection Agency*  
**REGIONAL WATER QUALITY CONTROL BOARD**  
**CENTRAL VALLEY REGION**

*Robert Schneider, Chair*  
*Karl E. Longley, Vice Chair*  
*Beverly Alves, Member*  
*Alson Brizard, Member*  
*Christopher Cabaldon, Member*  
*Mark Salvaggio, Member*

---

*Gary M. Carlton, Executive Officer*

---

3443 Routier Road, Suite A  
Sacramento, California 95827-3003

---

Phone: (916) 255-3000  
CalNet: 8-494-3000

*DISCLAIMER*

*This publication is a technical report by staff of the  
California Regional Water Quality Control Board, Central Valley Region.  
No policy or regulation is either expressed or intended.*

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY  
REGIONAL WATER QUALITY CONTROL BOARD  
CENTRAL VALLEY REGION

**Clear Lake TMDL for Mercury**  
**Numeric Target Report**

**Staff Report**

*June 2001*

**REPORT PREPARED BY:**

JANIS COOKE, PH. D.  
Environmental Scientist

And

JOE KARKOSKI  
Senior Land and Water Use Analyst

Sacramento River Watershed TMDL Unit



## **Clear Lake TMDL for Mercury Numeric Target Report**

### **EXECUTIVE SUMMARY**

Section 303(d) of the Federal Clean Water Act requires that States identify waterbodies that are not meeting water quality standards and develop total maximum daily pollutant loads for those waterbodies. A Total Maximum Daily Load (TMDL) represents the total loading rate of a pollutant that can be discharged to a waterbody and still meet the applicable water quality standards. A TMDL can be part of a plan to correct existing water quality problems. The purpose of the mercury TMDL for Clear Lake is to identify the mercury control measures and additional information needed to meet water quality standards and to guide the implementation of control measures and monitoring programs.

This report, "Clear Lake TMDL for Mercury: Numeric Target Report", presents the first major step in development of a TMDL for mercury in Clear Lake. The objectives of this report are to:

1. Describe the methodology that the Regional Board plans to use in determining water quality targets for mercury.
2. Present options for targets and for factors, such as acceptable intake levels of mercury that are incorporated into final target values.
3. Recommend numeric targets for the Clear Lake mercury TMDL that are protective of the beneficial uses of Clear Lake.

The numeric target recommendations result from a review of the best available data and a scientifically based evaluation of the risks posed by mercury in Clear Lake. Questions of economic or technical feasibility of reaching the target were not considered in determining the target recommendations. Feasibility and cost-benefit analyses will be addressed in the Regional Board's Basin Plan Amendment process, prior to final approval of the TMDL by the US Environmental Protection Agency.

This is the final draft version of the Target Report. The preliminary draft was released in August 2000. The preliminary draft has been revised based upon new information and comments from public and peer reviewers. Individual responses to all comments received are contained in Appendix C. The TMDL target will be incorporated in the TMDL Report, which will also include: quantification and location of all mercury sources; analysis of linkages between mercury entering Clear Lake and water quality endpoints; reductions in load from each source necessary to achieve targets, and margin of safety that considers seasonal variations and uncertainties. A draft of the TMDL Report will be completed by the Central Valley Regional Water Quality Control Board (Regional Board) and submitted to the U.S. Environmental Protection Agency (USEPA) in November 2001. At that point, USEPA will review and provide comments, but will not formally approve or disapprove. Finalization of TMDLs in California is a two-part process. First, the

TMDL will be incorporated into the State's Water Quality Control Plan for the Central Valley Region (Basin Plan). Amendment of the Basin Plan requires an extensive public review process and approval of the amendment by the Regional Board and the State Water Resources Control Board, and the State Office of Administrative Law. Second, after passage at the State level, TMDLs must be approved by the USEPA. Regional Board staff anticipates that the State process for amending the Central Valley Region Basin Plan to contain the Clear Lake mercury TMDL will be completed in late 2002 or 2003.

Mercury can be found in the environment in numerous chemical forms. One organic form, methylmercury, is the most hazardous form of mercury to mammals including humans, birds and aquatic animals. Within an organism, rates of intake of methylmercury tend to be greater than rates of elimination, such that it accumulates within tissues as the organism ages. Methylmercury also becomes increasingly concentrated in higher trophic levels of the food web.

Mercury adversely affects neurological, reproductive and immune systems. In humans, the nervous system during early development is the most sensitive organ system to toxic effects of mercury. In wildlife, sensitive endpoints are reproductive success, motor control and damage to the neural system detected microscopically after death. The primary route of exposure to mercury is through consumption of mercury-contaminated fish and other aquatic organisms.

Clear Lake in Lake County, California is considered by the Regional Board to be impaired due to mercury. High levels of mercury in fish are of concern to humans and wildlife that eat fish from Clear Lake. The California Department of Health Services issued a fish consumption advisory in 1987 (Stratton et al., 1987). Based upon high concentrations of mercury in fish tissue and the fish consumption advisory, the Regional Board placed Clear Lake on the Clean Water Act 303(d) List of Impaired Waterbodies in 1988. Elevated levels of mercury have also been measured in lake sediment, water, birds and other organisms from Clear Lake (CVRWQCB, 1985; Suchanek et al., 1997). The objective of the TMDL is to lower mercury levels so that the beneficial uses of Clear Lake as wildlife habitat and sport and recreational fishery are fully supported. Sources of mercury in Clear Lake include: the site of an inactive mercury mine on Oaks Arm, geothermal vents, erosion of mercury-enriched soil, urban and agricultural runoff, and atmospheric deposition.

## **Types of Targets**

Targets could be determined for mercury measurements in biota, water or sediment. Mercury measurements in the target media should be able to assess fairly directly whether beneficial uses are being met. The major beneficial uses of Clear Lake that are currently unmet are as a safe fishery for humans and wildlife. Therefore, a target of mercury in fish tissue would provide a direct measure of fishery conditions and improvement. Mercury data in fish from Clear Lake that have been collected since 1970 provide a good baseline from which to evaluate the success of future load reductions. A target of mercury in fish tissue, therefore, is proposed as the primary target type for the Clear Lake mercury TMDL.

Targets in other environmental media were evaluated and determined less appropriate for Clear Lake than a fish tissue target. Analyses of mercury in feathers and eggs are well-established methods for evaluating exposure of birds to mercury. Information needed to develop avian targets for Clear Lake is lacking. Threshold effect levels of mercury are unknown for fish-eating birds at Clear Lake that could be used as indicator species, such as mergansers, grebes, herons or osprey. Human hair has been used extensively to estimate exposures of individual humans to mercury. Human exposure to mercury in the Clear Lake region likely varies widely. It would be difficult to establish a baseline of human exposures from which to make future comparisons.

Existing data from Clear Lake show that sediment concentrations of mercury and methylmercury correlate poorly with concentrations of methylmercury in the water column or biota (Suchanek et al., 1997). The California Toxics Rule (CTR) mercury criterion does apply to Clear Lake. This criterion of 50 nanograms per liter (ng/L) total recoverable mercury in water is intended to protect human health from consuming contaminated organisms and drinking water. Regional Board staff does not consider the CTR value to be sufficiently protective of humans consuming fish from Clear Lake because of the low practical bioconcentration factors used to determine the CTR value. However, because the criterion is a definite goal that needs to be met in Clear Lake, it could be used as a secondary target for the TMDL.

### Potential Fish Tissue Targets for Human Health

A fish tissue target can be calculated using the following basic equation:

$$\frac{\text{Daily intake} * \text{Consumer's body weight}}{\text{Consumption rate}} = \text{Acceptable level of mercury in fish tissue}$$

Units in this equation are:

$$\frac{\mu\text{g Hg /kg bwt/day} * \text{kg bwt}}{\text{g fish/day}} = \mu\text{g Hg / g fish (ppm)}$$

Where:

Hg = mercury	g = gram
μg = microgram	kg = kilogram
bwt = consumer's body weight	ppm = parts per million

The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. Ingestion of seafood containing methylmercury is the most significant route of exposure. Mercury intake levels are based on studies of humans exposed to methylmercury in the diet. Retrospective studies have been made of effects of

methylmercury poisoning incidents in Minamata Bay, Japan and in Iraq (Bakir et al., 1973; Marsh et al., 1987; Tsubaki and Irukayama, 1977). These studies clearly showed that neonates and young children are most sensitive to toxic effects of methylmercury. More recently, long-term, cohort studies have been conducted within populations that regularly consume seafood contaminated with mercury (Grandjean et al., 1997; Davidson et al., 1998). These newer studies evaluated exposure during pregnancy and measured relatively subtle effects on fine motor control, memory, and audio-visual functions in children born to mothers who ate seafood.

The USEPA and the U.S. Agency for Toxic Substances and Disease Registry have developed daily intake levels based upon the most sensitive measure of toxicity known, which is neurodevelopmental impairment in children whose mothers consumed methylmercury during pregnancy. Regional Board staff recommends using the USEPA reference dose of 0.1 µg mercury/kg bwt/day for calculation of the TMDL targets. The USEPA reference dose value was originally based upon data from a mass-poisoning incident in Iraq. It was revised in the year 2000 and is now based upon data from a population in the Faroe Islands that consumes fish regularly (USEPA, 2001b). The USEPA revision was guided significantly by a comprehensive review of the literature and recommendations published by a panel of the National Academy of Sciences (NRC, 2000). The U.S. Food and Drug Administration (USFDA) daily intake level, which corresponds to the USFDA action level of 1.0 milligram per kilogram (mg/kg) mercury in fish tissue, is not considered appropriate for the TMDL. The USFDA levels were designed only to protect adults consuming a variety of commercial fish and shellfish.

An average bodyweight of 65 kg is recommended for use in developing the target. This is USEPA's standard bodyweight for pregnant females. To best ensure that a mercury target protects the unborn, it is logical that an average adult consumer be represented as a pregnant female. This bodyweight is also intermediate between standard bodyweights used for males (70 kg) and females (60 kg). Conversion factors are available to adjust the target for other bodyweights (OEHHA, 1999). Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size.

The most difficult of the variables to define is the consumption rate. One small consumption study has been completed for members of the Elem Tribe and several neighbors of the Sulphur Bank Mercury Mine at Clear Lake (Harnly et al., 1997). Participants reported eating an average 60 grams per day (g/day) of Clear Lake fish, however, the average was heavily influenced by high consumption rates of a few individuals. Consumption rate of the 90<sup>th</sup> percentile of study participants was 30 g/day of Clear Lake fish. At least some participants ate commercial fish as well. Species consumed in the greatest amounts were catfish and perch. Consumption information for the general population at Clear Lake has not been collected.

Consumption rates of fish and other seafood determined in various national and regional studies vary widely. Consumers are exposed to mercury in sport as well as commercial fish. Consumption studies have been reviewed extensively by the California Office of Environmental



Health Hazard Assessment and in the Mercury Study Report to Congress (Gassel et al., 1997; USEPA, 1997b). Mean consumption rates for consumers-only (people who eat no fish were not included) range from 9 to 111 g/day. Consumption rates for consumers in the 90<sup>th</sup> to 95<sup>th</sup> percentiles range from 65 to more than 200 g/day. The USEPA has identified consumption rates based on a 1993-94 nationwide dietary survey (USEPA 2000b). The USEPA default rate for the general population is 17.5 g/day of locally caught fish, which is the consumption rate for the 90<sup>th</sup> percentile of those surveyed. The national survey found that the average consumption rate of commercial fish was 12.5 g/day and that many consumers eat both commercial and locally caught fish. Creel surveys at Clear Lake suggest that the ratio of trophic level four to trophic level three fish caught and consumed from Clear Lake is higher than the national average (Macedo, 1991).

For numeric targets for the Clear Lake Mercury TMDL, Regional Board staff proposes using 0.13 and 0.30 mg methylmercury/kg wet weight of fish tissue (ppm) in trophic levels 3 and 4 fish, respectively. To obtain these targets, fish tissue concentrations corresponding to safe consumption of 17.5 g/day of local fish were calculated, then lowered by a small, additional safety factor. These targets are derived from consumption patterns of trophic level 3 and 4 fish that are based upon creel surveys conducted in Clear Lake. Meeting these targets would require a forty percent reduction from current fish tissue levels. These targets assume that consumers eat an additional 12.5 g/day of commercial fish, such as scallops and tuna.

Regional Board staff recommends that a consumption survey be conducted to better define consumption patterns for the general population at Clear Lake. Some members of the Elem Pomo Tribe and non-tribal neighbors reported eating more than 17.5 g/day of fish from Clear Lake. Consumers eating more than 17.5 g/day are protected by a margin of safety comprised of the uncertainty factor in the reference dose and by setting the targets below the levels needed to meet acceptable daily intakes of methylmercury (40% reduction from current fish tissue levels instead of 35%).

These targets are recommended by Regional Board staff, based on scientific merit. Technical and economic feasibilities of reaching the target, which are not addressed in this report, will be addressed in the final TMDL Report.

### **Potential Fish Tissue Targets for Wildlife Health**

Wildlife species potentially at risk from toxic effects of mercury are those that eat fish or other aquatic organisms that contain mercury. Species of concern at Clear Lake include river otter, raccoon, mink, herons, grebes, bald eagles and osprey.

The same method described above for humans can be used for wildlife to determine safe fish tissue concentrations. The above basic equation can also be rearranged to determine the average daily intake of mercury for different wildlife species consuming fish from Clear Lake with known

levels of mercury. The average daily intake can then be compared with acceptable daily intake levels published in scientific literature.

Many studies have been published that address mercury in wildlife; however, there are relatively few studies that link known exposure levels to quantifiable effects. A set of feeding studies in mink is used to determine acceptable daily intake levels for fish-eating mammals (USEPA, 1995b; USEPA, 1997c). The single-generation investigations in mink evaluated endpoints of survival, growth rates, motor control and histologic assessment of neuronal damage, but not reproduction. The acceptable daily intake level used for mammalian wildlife is 18 µg mercury/kg bwt/day (USEPA, 1997c). An acceptable daily intake level for fish-eating birds is based on results of a three-generation study of mallard ducks by Heinz and colleagues (Heinz, 1974; Heinz, 1976a; Heinz, 1976b; Heinz, 1979). The daily intake value of 21 µg/kg bwt per day determined in the Mercury Study Report to Congress is used for calculations in this report (USEPA, 1997c).

Mammalian and avian acceptable daily intake values were compared with estimated actual daily intakes of wildlife at Clear Lake. These comparisons showed that wildlife that consume fish from Clear Lake are highly likely to exceed acceptable daily intake levels of mercury. Mercury intake by river otters is estimated to be at least twice the acceptable daily intake level and by kingfishers to be about three times the acceptable level. For raptorial birds, intake may be at or slightly higher than acceptable daily levels.

Because of uncertainties in reference doses, consumption patterns of Clear Lake fish, and whether wildlife at Clear Lake are being adversely impacted by mercury, Regional Board staff is not recommending separate fish tissue targets to protect wildlife. Instead of setting targets for wildlife, the effects on wildlife intakes of methylmercury of achieving the human health targets were examined. If mercury concentrations in fish eaten by wildlife were reduced by 40%, all species of concern except for river otter and kingfisher are expected to be protected. Bird species identified as particularly sensitive, western grebes and common mergansers, would be protected at the recommended TMDL targets. Using the recommended Clear Lake targets and literature values for consumption, it is estimated that river otter and kingfisher would still exceed the respective safe daily intake levels of methylmercury for mammals and birds. To achieve safe intake levels for river otters, an additional 10% reduction from current fish tissue levels would be required. No information is available on health of river otters at Clear Lake. Methylmercury intake by kingfishers may be overestimated. Kingfishers likely eat the smallest fish available, which have less methylmercury than the average concentration in trophic level 2-3 fish used to calculate the intake. Because the Regional Board is committed to protecting all species at risk at Clear Lake, staff will evaluate any new information relative to wildlife risks prior to amending the Clear Lake TMDL targets into the Basin Plan.

The recommended numeric targets contain a margin of safety for wildlife that eat fish from Clear Lake. The avian and mammalian reference doses each contain an uncertainty factor of three. These uncertainty factors lower the reference doses below levels of mercury known to cause

adverse effects to mallards and mink, respectively. Although the uncertainty factors were not applied to account for species differences, they do provide some measure of protection to wildlife that may be more sensitive to effects of mercury.

## Table of Contents

EXECUTIVE SUMMARY .....	i
Types of Targets .....	ii
Potential Fish Tissue Targets for Human Health.....	iii
Potential Fish Tissue Targets for Wildlife Health .....	v
Table of Contents.....	viii
List of Tables .....	x
List of Figures .....	x
List of Acronyms .....	xi
Units of Measure.....	xii
Clear Lake TMDL for Mercury Numeric Target Report INTRODUCTION.....	1
Toxicity of Mercury.....	1
Mercury Chemistry and Accumulation by Biota.....	2
Sources of Mercury.....	4
Clean Water Act 303(d) Listing and Total Maximum Daily Load Development .....	5
How will the target be used?.....	7
How does the numeric target fit into the overall strategy to address mercury in Clear Lake?.....	8
What is the Timeline and Process for the Clear Lake Mercury Management Strategy?.....	9
SELECTION OF TYPE OF TARGET .....	9
Fish Tissue .....	9
Other Biota.....	10
Sediment .....	11
Water.....	12
Key Points – Selection of Type of Target.....	14
POTENTIAL HUMAN HEALTH TARGETS.....	14
Fish Tissue Target Equation .....	15
Equation 1 .....	16
Equation 2 .....	16
Acceptable Daily Intake Level – Options.....	16
Acceptable Daily Intake Level – Recommendations.....	20
Key Points – Calculation of Fish Tissue Target and Selection of Human Health Reference Dose .....	22
Body Weight and Portion Size – Options.....	22
Body Weight and Portion Size – Recommendation .....	23
Consumption Rate – Options.....	23
National Consumption Surveys .....	25
Local Consumption Data .....	28
Regional Consumption Data.....	29
Other Sport and Locally Caught Fish Consumption Data .....	30

USEPA Consumption Rates .....	31
Consumption of Fish from Various Trophic Levels .....	32
Mercury Exposure from Commercial Fish .....	33
Margin of Exposure Analysis for Elem Pomo and Others .....	34
CONSUMPTION RATE AND NUMERIC TARGET – RECOMMENDATIONS .....	35
Margin of Safety in the Numeric Target for Humans .....	38
Figure 1. Sample Calculation of the Proposed Numeric Targets for Humans .....	39
Equation 1 SAFE INTAKE LEVEL FROM LOCAL FISH .....	39
Key Points – Human Body Weights, Portion Size, Consumption Rates and Numeric Targets .....	41
Comparison with Existing Fish Tissue Values .....	41
USFDA Action Level and Other Screening Levels .....	42
USEPA Fish Tissue Criterion .....	42
POTENTIAL WILDLIFE HEALTH TARGETS .....	44
Mammals .....	44
Avian Species .....	45
Mercury in Wildlife at Clear Lake .....	46
Western Grebes .....	46
Additional Bird Species .....	47
Mammalian Wildlife .....	48
Potential Numeric Targets for Wildlife .....	49
Reference Doses .....	50
Body weights and Consumption Rates .....	50
Existing Mercury Concentrations in Clear Lake Fish .....	51
Estimated Daily Intakes of Methylmercury and Numeric Targets for Wildlife .....	52
Margin of Safety for Wildlife .....	54
Key Points – Potential Wildlife Health Targets .....	57
REFERENCES .....	57
APPENDIX A. Concentrations of Mercury in Clear Lake Fish .....	A-1
APPENDIX B. Assessment of Human Exposure to Mercury at Clear Lake .....	B-1
APPENDIX C. Response to Comments .....	C-1

## List of Tables

Table 1.	1998 Clean Water Act Section 303(d) List of Waterbodies Impaired Due to Mercury in the Central Valley .....	6
Table 2.	Existing and Potential Beneficial Uses of Clear Lake (Source: Central Valley Region Basin Plan, 1998.) .....	6
Table 3.	Seafood Consumption Rates .....	26
Table 4.	Consumption of Clear Lake Fish by Members of the Elem Pomo Tribe and Non-tribal Neighbors .....	28
Table 5.	Principal Sport Fish in Clear Lake .....	32
Table 6.	Margin of Exposure Analysis of Bioindicators in Fish Consumers Living near SBMM .....	34
Table 7.	Estimated Exposures to Humans Eating Clear Lake Fish and Proposed Numeric Targets .....	40
Table 8.	Fish Tissue Screening Values and Criterion .....	43
Table 9.	Mercury Effects in Mink .....	45
Table 10.	Nesting Success of Western Grebes at Clear Lake and Other Western Lakes (Source: Elbert & Anderson, 1998) .....	47
Table 11.	Exposure Parameters for Fish-eating Wildlife .....	52
Table 12.	Estimated Methylmercury Intake by Wildlife at Clear Lake and Comparison with Acceptable Intakes .....	55
Table 13.	Effect on Wildlife Intakes of Methylmercury of Forty Percent Reduction in Current Fish Tissue Levels .....	56

## LIST OF FIGURES

Figure 1.	Sample Calculation of the Proposed Numeric Targets for Humans .....	40
-----------	---	----

## LIST OF ACRONYMS

303(d) List	Clean Water Act 303(d) List of Impaired Waterbodies
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BAF	bioaccumulation factor
Basin Plans	Water Quality Plans
BCF	bioconcentration factor
bwt	body weight
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services
CTR	California Toxics Rule
CWA	federal Clean Water Act
GLWQI	Great Lakes Water Quality Initiative Final Rule
Hg	Mercury
LOAEL	lowest-observable adverse effect level
MOE	Margin of Exposure
MRC	Mercury Study Report to Congress
MRL	ATSDR Minimal Risk Level
N	population size
NAS	National Academy of Sciences
NOAEL	no-observable adverse effect level
NRC	National Research Council
OEHHA	Office of Environmental Health Hazard Assessment
PCBs	polychlorinated biphenyls
ppm	Part per million (Examples: mg/kg or mg/L)
Regional Board	Central Valley Regional Water Quality Control Board
RfD	reference dose
SBMM	Sulphur Bank Mercury Mine
SDCDHS	San Diego County Department of Health Services
State Board	State Water Resources Control Board
Target Report	Clear Lake Mercury TMDL Numeric Target Report
TL3	trophic level 3
TL4	trophic level 4
TMDL	Total Maximum Daily Load
TMDL Report	Clear Lake Mercury TMDL Report
UC Davis	University of California-Davis
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFDA	U.S. Food and Drug Administration
USFWS	U.S. Fish and Wildlife Service
WHO	World Health Organization

## UNITS OF MEASURE

µg	microgram
µg/g	microgram per gram
µg/L	microgram per liter
µm	micrometer
cm	centimeter
g	gram
g/day	gram per day
g/L	gram per liter
kg	kilogram
L	liter
m	meter
mg	milligram
mg/g	milligram per gram
ml	milliliter
mm	millimeter
ng	nanograms
ng/L	nanograms per liter



## **Clear Lake TMDL for Mercury Numeric Target Report**

### **INTRODUCTION**

Mercury (Hg) is a widespread environmental contaminant. In some waterbodies, mercury concentrations may reach levels that adversely affect humans and wildlife. It is a potent neurotoxin that also affects reproductive, cardiovascular, and immune systems. The purpose of this document is to describe the derivation of water quality targets for mercury that are designed to protect beneficial uses of the water and resources of Clear Lake, California by humans and wildlife. This is the final draft version of the Numeric Target Report (Target Report). The Central Valley Regional Water Quality Control Board (Regional Board) released the preliminary draft in August 2000. The preliminary draft has been revised based upon new information and comments from public and peer reviewers. Individual responses to all comments received are contained in Appendix C. The Total Maximum Daily Load (TMDL) target will be finalized in the Clear Lake Mercury TMDL Report (TMDL Report). Final water quality targets will be derived based upon consideration of beneficial uses, economics and feasibility. The final water quality targets will be used for the mercury TMDL program for Clear Lake.

### **Toxicity of Mercury**

Mercury is a potent neurotoxin. Developing fetuses and young children are at greatest risk of toxicity from mercury (NRC, 2000). Although the inhalation of elemental mercury fumes can cause harm, exposure to levels of concern most frequently occurs through the consumption of methylmercury in fish tissue. The aquatic food web provides more than 95% of humans' intake of methylmercury (USEPA, 1997c). Toxicity of mercury to humans has been documented in populations consuming contaminated fish (Davidson et al., 1998; Grandjean et al., 1997; Tsubaki and Irukayama, 1977) and grains treated with methylmercury-containing fungicide (Bakir et al., 1973). Consumption of highly contaminated fish caused multiple effects, including tingling or loss of tactile sensation (paresthesia), loss of muscle control, blindness, paralysis, birth defects and death. Children whose mothers ate fish during pregnancy may be at risk for more subtle behavioral and neurodevelopmental impairments (Crump et al., 1998; Davidson et al., 1998; NRC, 2000). Children who eat fish themselves are also believed to be more sensitive than adults to mercury because their neural systems are still developing and they tend to consume more fish per body weight than adults (Grandjean et al., 1999; Mahaffey, 1999). Effects in children exposed early in development appear at dose levels five to ten times lower than dose levels associated with toxicity in adults (NRC, 2000).

Although the largest body of literature addresses effects of mercury on neurodevelopment, studies have found impairment of other organ systems, as well. Exposure to mercury has been found to

cause reduced fertility, adverse cardiovascular effects, and immunotoxicity, and to alter cell division (NRC, 2000; Speirs and Speirs, 1998).

Effects of mercury are dependent upon the dose received. Levels of mercury in fish from Clear Lake are much lower (0.2 - 1.8 mg mercury /kg, wet weight for top predator fish) (CVRWQCB, 1985) than levels in fish that poisoned consumers in Minamata Bay (fish levels up to 50 mg/kg). There is no current evidence of acute or chronic mercury toxicity to humans due to consumption of fish from Clear Lake or Cache Creek. Extensive fish consumption and effect studies in the region, however, have not been conducted. Existing fish consumption advisories for Clear Lake, presented in terms of pounds of fish than can be safely consumed, are based upon the risk for average adult consumers of developing a non-fatal, neurologic impairment of paresthesia. Pregnant women, women who may soon become pregnant, nursing mothers and children under age six are advised not to eat fish from Clear Lake (Stratton et al., 1987).

Wildlife species also exhibit detrimental effects from mercury exposure. Behavioral effects including impaired learning, reduced social behavior and impaired physical abilities have been observed in mice, otter, mink and a primate species (crab-eating macaques) exposed to methylmercury (Wolfe et al., 1998). Reproductive impairment following mercury exposure has been observed in multiple species, among them common loons and western grebe (Wolfe et al., 1998), walleye (Whitney, 1991 in Huber, 1997) and mink (Dansereau et al., 1999). Limited studies conducted to date with Clear Lake wildlife have found no adverse effects or reproductive impairments that are conclusively linked to mercury exposure (Elbert, 1996; Suchanek et al., 1997; Wolfe and Norman, 1998).

### **Mercury Chemistry and Accumulation by Biota**

Mercury can exist in various forms in the environment. Chemically, mercury can exist in three oxidation states: elemental ( $\text{Hg}^0$ ), mercurous ion (monovalent,  $\text{Hg}^{+1}$ ), or mercuric ion (divalent,  $\text{Hg}^{+2}$ ). Ionic mercury can react with other chemicals to form inorganic compounds (such as cinnabar,  $\text{HgS}$ ) or organic compounds (such as methylmercury or dimethylmercury). Physically, mercury may be present in air as mercury vapor, dissolved in the water column, or associated with solid particles in air, water or soil.

Both inorganic mercury and organic mercury can be taken up from water, sediments and food by aquatic organisms. Because rates of uptake are generally much greater than rates of elimination, mercury concentrates within organisms. For low trophic level species such as phytoplankton, most mercury is obtained directly from the water. *Bioconcentration* describes the net accumulation of mercury directly from water. The bioconcentration factor (BCF) is the ratio of mercury concentration in an organism to mercury concentration in water. Most mercury in predatory species such as piscivorous fish and birds, however, is obtained from mercury-containing prey rather than directly from the water (USEPA, 1997d). A bioaccumulation factor (BAF) describes the degree to which mercury accumulates from water and prey, relative to

mercury concentration in the water. Compounds *bioaccumulate* when rates of uptake are greater than rates of elimination.<sup>1</sup>

Repeated consumption and accumulation of mercury from contaminated food sources results in tissue concentrations of mercury that are higher in each successive level of the food chain. This process is termed *biomagnification*. Methylmercury readily accumulates in fish due to efficient uptake from dietary sources and low rates of elimination. The proportion of total mercury that exists as the methylated form generally increases with level of the food chain, approaching greater than 90% in top trophic level fish (Nichols et al., 1999). This occurs because inorganic mercury is less well absorbed and/or more readily eliminated than methylmercury. Field studies indicate that diet is the primary route of mercury uptake by fish (Wiener and Spry, 1996). Methylmercury is the predominant form of organic mercury present in biological systems. Dimethylmercury is not considered to be a concern in freshwater systems. It is an unstable compound that dissociates to methylmercury at neutral or acid pH (USEPA, 1997c).

Diet is also the primary route of methylmercury exposure for organisms that consume fish and aquatic invertebrates. Although a few studies have indicated that methylmercury impairs reproduction of some fish (Huber, 1997; Wiener and Spry, 1996), the greatest concern for mercury toxicity is in higher trophic-level organisms that consume seafood. Wildlife species of potential concern in the Central Valley waterbodies for which mercury TMDLs will be developed include: herons, egrets, mergansers and other fish-eating waterfowl; bald eagles; osprey; mink; raccoon and otter.

Aquatic ecosystems tend to have higher rates of mercury bioaccumulation and biomagnification than do terrestrial ecosystems (USEPA, 1997c). There are several factors contributing to this difference. Fish store most mercury as methylmercury in their muscle, while mammals and birds store much of their methylmercury burden in feathers, hair or fur. Deposition to hair, feathers and fur provides mammals and birds a mercury excretory pathway that is unavailable to fish. Aquatic systems tend to have more complex food webs and more trophic levels, which contributes to greater biomagnification. Some primary producers in aquatic systems accumulate more mercury from water and sediment than do soil-based primary producers in terrestrial systems (USEPA, 1997c).

---

<sup>1</sup> The differences between BCF and BAF are not always clear. BCF are generally determined in the laboratory by measuring concentration in an organism after being placed for a discrete period of time in water with a known concentration of mercury. A BCF calculated this way would measure mercury taken in by passive absorption and drinking, but not by eating. A BAF is determined from field data as the ratio between organism concentration and water column concentration of mercury, which would include the mercury consumed by the organism in its prey. Human and wildlife criteria issued by the USEPA in the Final Water Quality Guidance for the Great Lakes System were determined using BAFs (USEPA, 1995b). In deriving criteria in the California Toxics Rule, the USEPA used what they term “practical bioconcentration factors”. The practical BCFs have been used by the USEPA since 1980 and were derived in a way to “take into account uptake from food as well as uptake from water” (USEPA, 2000a).

## Sources of Mercury

The Coast Range of California is a region naturally enriched in mercury. Active geothermal vents and hot springs deposit mercury, sulfur and other minerals at or near the earth's surface. Extensive mining of mercury in the Coast Range began in the early 1800s. Much of the mercury produced in the Coast Range was used to recover gold in the Sierra Nevada Mountains during the Gold Rush period. Mercury mining exacerbated the amount of mercury entering some waterbodies due to erosion, weathering and even mass dumping of mercury-containing ores. High levels of mercury are present in some streams and lakes in the Coast Range and Sierra Nevada, the Sacramento River, and the Sacramento – San Joaquin River Delta.

Clear Lake is a polluted by mercury. Water quality investigations in Clear Lake conducted by the Regional Board, California Department of Health Services (CDHS), California Department of Fish and Game (CDFG), and U.S. Geological Survey at various times since 1970 have shown elevated levels of mercury in water, lake sediment, and biota (CVRWQCB, 1985). One current and historical source of mercury entering the lake is the Sulphur Bank Mercury Mine (SBMM) site. SBMM, located on the Oaks Arm of Clear Lake, was among the nation's ten largest mercury mines in terms of total production. The mine is now inactive. Mercury extraction from shafts started at Sulphur Bank in 1872. Mining continued using open pit methods from 1927 until operations ceased in 1957. SBMM was declared a federal Superfund site in 1991. Two remediation projects have been completed:

1. Regrading and vegetation of mining waste piles along the shoreline that decreased mass erosion into the lake.
2. Construction of a surface water runoff diversion system that prevents clean runoff from flowing over mercury-containing waste rock piles.

The U.S. Environmental Protection Agency (USEPA) is currently conducting a remedial investigation to fully characterize the SBMM site and propose a final remedy. Additional sources of mercury may include geothermal vents and hot springs, urban and agricultural runoff, erosion of naturally mercury-enriched soils, and atmospheric deposition. In the Upper Arm of Clear Lake, wild rice fields that are irrigated with water from Clear Lake could be sites of production of methylmercury, which then drains back into the lake *via* Middle Creek and Rodman Slough. Loading estimates from these sources will be part of the TMDL Report.

Mercury cycling, transport, methylation, and sources are all complex topics that are only discussed briefly in this report. While not yet completely understood, a great deal of literature has been published about of mercury in the environment. For additional information about mercury cycling, transformations, and general sources, the reader is referred to the Mercury Study Report to Congress and other review papers (Sigel and Sigel, 1997; SRWP, 2000b; USEPA, 1997a; USEPA, 1997b).

## **Clean Water Act 303(d) Listing and Total Maximum Daily Load Development**

High levels of mercury in fish are of concern to humans and wildlife that eat fish from Clear Lake. CDHS issued a fish consumption advisory in 1987 (Stratton et al., 1987). In 1988, the Regional Board placed Clear Lake on the federal Clean Water Act (CWA) 303(d) List of Impaired Waterbodies (303(d) List), based upon high levels of mercury in fish and waterfowl and the existence of the fish consumption advisory. Elevated levels of mercury have also been measured in lake sediment, water, birds and other organisms from Clear Lake (CVRWQCB, 1985).

Mandated under Section 303(d) of the CWA, the 303(d) List for the Central Valley is prepared by the Regional Board and approved by the State Water Resources Control Board (State Board) and the USEPA. Updates to the 303(d) List are prepared every two years. Other waterbodies listed as impaired due to mercury are shown in Table 1.

By definition, an impaired waterbody does not support all of its designated beneficial uses. Water Quality Plans (Basin Plans) prepared by each Regional Water Quality Control Board and approved by the State Board list the designated beneficial uses for each waterbody. Beneficial uses identified for Clear Lake are shown in Table 2 (CVRWQCB, 1998).

Waterbodies on the 303(d) List are not expected to meet water quality standards even if dischargers of point sources comply with their current discharge permit requirements. One tool to address ongoing issues of contamination from nonpoint and point sources is the setting of TMDLs. The federal CWA mandates that TMDLs be developed for all waterbodies on the 303(d) List. A TMDL represents the maximum load (usually expressed as a rate, such as grams/day [g/day]) of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL contains the reductions needed to meet water quality standards and allocates those reductions among the sources in the watershed. In California, a RWQCB develops a TMDL and submits it to the USEPA for approval. Elements that must be included in a TMDL are as follows:

- numerical water quality target;
- identification of sources;
- maximum load of the contaminant that will not adversely impact beneficial uses;
- mathematical linkage between the water quality target and amount of contaminant (a linkage analysis is used to determine the amount by which current pollutant levels must be reduced in order to achieve the maximum load);
- allocation of portions of the necessary load reduction to the various sources; and
- margin of safety in the maximum load determination that takes into account uncertainties and seasonal variations.

Table 1. 1998 Clean Water Act Section 303(d) List of Waterbodies Impaired Due to Mercury in the Central Valley

Waterbody	Total Size	Impaired Size	Priority
<b>Sacramento River Watershed</b>			
American River, downstream of Folsom Dam	30 miles	23 miles	medium
Cache Creek	60 miles	35 miles	high
Feather River, downstream of Oroville Dam	60 miles	60 miles	medium
Humbug Creek	9 miles	9 miles	low
Harley Gulch (flows to Cache Creek)	8 miles	8 miles	medium
James Creek (flows to Lake Berryessa)	6 miles	6 miles	low
Sacramento Slough	1 mile	1 mile	medium
Sacramento River (between City of Red Bluff & the Delta)	185 miles	30 miles	high
Sulfur Creek (flows to Bear Creek, then to Cache Creek)	7 miles	7 miles	high
Clear Lake	43,000 acres	43,000 acres	high
Davis Creek Reservoir	290 acres	290 acres	medium
Lake Berryessa	20,700 acres	20,700 acres	high
<b>San Joaquin River Watershed and Delta</b>			
Dunn Creek (flows to Delta)	9 miles	9 miles	low
Marsh Creek (flows to Delta)	24 miles	24 miles	medium
Marsh Creek Reservoir	375 acres	375 acres	medium
Panoche Creek (flows to San Joaquin River)	50 miles	25 miles	medium
San Carlos Creek	1 mile	1 mile	low
Waterways in the Sacramento-San Joaquin River Delta	480,000 acres	480,000 acres	high

Table 2. Existing and Potential Beneficial Uses of Clear Lake  
(Source: Central Valley Region Basin Plan, 1998.)

Beneficial Use	Status
Municipal and domestic water supply	existing
Agriculture - irrigation	existing
Agriculture - stock watering	existing
Contact recreation (ex. swimming, skiing)	existing
Canoeing and rafting	existing
Other non-contact recreation (ex. boating, picnicking)	existing
Warm water fish habitat	existing
Spawning area for warm water fish	existing
Wildlife habitat	existing (a)
Sport/Recreational fishery	existing (a)
Cold water fish habitat	potential

(a) Beneficial uses determined by the Regional Board and USEPA to be impaired by mercury in Clear Lake.

*How will the target be used?*

Regional Board staff will propose that the Regional Board adopt as water quality objectives those numeric targets that identify the ultimate goal (in terms of beneficial use protection) for a particular contaminant. When adopting water quality objectives, the Regional Board is required to reasonably protect beneficial uses and consider all of the following factors when setting those objectives:

“(a) Past, present, and probable future beneficial uses of water. (b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto. (c) Water quality conditions that could be reasonably achieved through the coordinated control of all factors that affect water quality in the area. (d) Economic considerations. (e) The need for developing housing within the region. (f) The need to develop and use recycled water.” *Porter-Cologne Water Quality Act §13241*

Regional Board staff may also propose that the Regional Board adopt other numeric targets that serve as indicators of progress in achieving the ultimate water quality objectives (e.g., targets for other media or interim targets) or targets that aid in relating implementation actions to attainment of the water quality objective (e.g., source specific and total mass loading targets).

This target report focuses primarily on factor “a” under §13241 of the Porter-Cologne Water Quality Act. Regional Board staff anticipates that the primary factors that could affect the final target include “b”, “c”, and “d”. Current investigations being conducted by the University of California-Davis (UC Davis) Clear Lake Environmental Research Center and the USEPA Superfund program for Clear Lake will provide the information needed to consider the other factors (b, c, and d).

The Regional Board is also required to comply with the federal CWA when establishing water quality objectives (referred to as “water quality standards” under the CWA). CWA §303(c) requires the State to establish water quality standards that protect the designated uses of the waters for which the standard is being established. In contrast to the Porter-Cologne Water Quality Act, the CWA allows States to consider attainability through the process of designating uses of waters (40 CFR §131.10 et. seq.), rather than through the process of establishing standards. If a use is already identified, the State may remove a designated use (as long as it is not an existing use) or create a sub-category of use.

To remove or modify a designated use, the State must demonstrate that one or more of the following factors prevent attainment of the designated use:

- naturally occurring pollutant concentrations;
- natural flow conditions;

- human-caused conditions that can not be remedied or correction for which would create greater environmental damage;
- hydromodification;
- physical conditions related to natural features; and/or
- more stringent controls would cause widespread social and economic impact (see 40 CFR §131.10(g) for a full description of these factors).

States may not remove designated uses if “Such uses will be attained by implementing effluent limits required under section 301(b) and 306 of the Act and by implementing cost-effective and reasonable best management practices for non-point source control” (40 CFR § 131.10(h)(2)).

Taken together, the requirements of the Porter-Cologne Water Quality Act and the CWA allow the Regional Board to adopt water quality objectives that are not “fully protective” of the currently designated uses of Clear Lake. The CWA requires the Regional Board to modify the currently designated use to a use that could be attained. Both the CWA and Porter-Cologne Water Quality Act require the Regional Board to demonstrate that currently designated uses cannot be attained due to natural conditions, technical feasibility, and/or economic impact. Such a designation requires a substantial burden of proof.

*How does the numeric target fit into the overall strategy to address mercury in Clear Lake?*

In general, Regional Board staff will develop a water quality management strategy for each waterbody and pollutant in the Central Valley identified on California’s 303(d) List. That strategy will include several phases: TMDL Development, Implementation Planning, Basin Planning, and Implementation.

The TMDL Development phase will include the technical analysis of the sources of pollutant, the fate and transport of those pollutants, the numeric target(s), and the amount of pollutant reduction that is necessary to attain the target. The Implementation Planning phase will include an evaluation of the practices and technology that can be applied to meet the necessary load reductions, the identification of potentially responsible parties, a description of the implementation framework (e.g. incentive-based, waste discharge requirements, and prohibitions), a time schedule for meeting the target(s), and a consideration of cost. The Basin Planning phase will focus on the development of a Basin Plan Amendment and a Functionally Equivalent Document for Regional Board consideration. The Basin Plan Amendment will include those policies and regulations that the Regional Board believes are necessary to attain water quality objectives. The Functionally Equivalent Document includes information and analyses required to comply with the California Environmental Quality Act. In general, the water quality management strategy presented to the Regional Board will include water quality objectives and a program of implementation (§13241 and §13242 of the Porter-Cologne Water Quality Act), including those elements necessary to meet Federal Total Maximum Daily Load requirements (CWA Section 303(d)).



### *What is the Timeline and Process for the Clear Lake Mercury Management Strategy?*

Regional Board staff is currently working on the TMDL Development phase of the Clear Lake mercury management strategy. This phase should be complete in summer 2001 with the release of the TMDL Report. The Implementation Planning phase will rely heavily on the evaluation of remedial options being conducted by the USEPA's Superfund program for the Sulfur Bank Mine site. The results of USEPA's evaluation, and other public input on implementation options, could provide support for modification of the recommendations in the TMDL Report. The Implementation Planning phase should be complete by March 2002. Any modifications to the TMDL Report would be contained in the proposed Basin Plan Amendment, along with the accompanying Functionally Equivalent Document and staff report, which will be presented to the Regional Board for adoption. Should an evaluation of implementation options indicate that the uses could not be reasonably attained, Regional Board staff may prepare a Use Attainability Analysis as part of the Basin Plan Amendment. Regional Board staff anticipates proposing a Basin Plan Amendment to the Regional Board by December 2002.

Regional Board staff intends to seek public input throughout the TMDL Development and Implementation Planning phases. As Regional Board staff develops documents related to preparation of the Basin Plan Amendment, formal public workshops and hearings will be held.

### **SELECTION OF TYPE OF TARGET**

Mercury is present in Clear Lake in sediment, water and biota. In theory, a target could be developed for any of these environmental compartments. In this section, environmental compartments will be evaluated for their applicability to the TMDL. Criteria for evaluating possible target media and evaluation results are also given in a target report prepared for the Sacramento River Watershed Program (SRWP, 1999). Targets appropriate for the TMDL should address as directly as possible whether beneficial uses are being attained. In the case of mercury, the beneficial uses unmet in Clear Lake are recreational and sport fishery and wildlife habitat.

Other characteristics to be considered for the target include:

- whether variability can be modeled and causes of variability are understood;
- whether ambient levels correlate with effects;
- whether measurements of target level would reflect mass load reductions in a timely manner; and
- the extent of remaining data gaps in the technical support of the target.

### **Fish Tissue**

Fish tissue is proposed as the primary target type for this TMDL. Contaminated fish is the primary source of mercury for humans and wildlife species of concern. Adverse effects of mercury have been examined for at least some wildlife species and for humans (for reviews, see USEPA, 1997c;

USEPA, 1997d; Wolfe et al., 1998). Levels of mercury exposure in consumers can be estimated from these studies and known concentrations of mercury in fish. A fish tissue target, then, provides a direct measure of improvement in the capacity of Clear Lake to fully support its use as a fishery. Mercury data in fish from Clear Lake have been collected since 1970, providing a good baseline from which to evaluate the success of future load reductions (Stratton, 1987; Suchanek, et al., 1997; Suchanek et al., 2000). Clear Lake or region-specific values for bioaccumulation factors and consumption rates could be used to calculate fish tissue levels that are protective of wildlife and humans.

In January 2001, the USEPA released its recommended water quality criterion for methylmercury in the form of a fish tissue concentration (USEPA, 2001b). In addition, the criteria document encourages the use of site-specific information, if available, to identify safe fish tissue levels. The USEPA criterion sets a precedent for use of a fish tissue concentration to protect beneficial uses.

## **Other Biota**

Tissues of mammals and birds that consume fish are also potential types of targets. Mercury concentrations in various internal organs, blood, hair, fur and feathers have been reported. For mammals including humans, the most useful of these media are hair and blood. Human hair has been used extensively to estimate exposures of individuals to mercury (USEPA, 1997d). Mercury in sections of hair strands can be used to estimate exposure during a discrete time period (such as pregnancy) or the average exposure during growth of the strand. Levels of mercury in blood reflect relatively recent exposures. Particularly for people consuming relatively low amounts of fish, mercury in hair or blood appear to correlate better with assessment of adverse effects than exposure estimates based on recall of consumption from memory (Gassel et al., 1997; Harnly et al., 1997).

Targets based on human and other mammalian measurements have similar disadvantages. Sometimes wide variations are caused by differences in exposure, due to changes in sizes, amounts and species of fish consumed, and in metabolism of mercury. For example, half-lives of mercury in adult humans can vary by a factor of two or more (USEPA, 1997d). Trapping fish-eating mammals is difficult and, depending upon the study population, may not provide enough samples for statistical analysis (Wolfe and Norman, 1998). For either humans or mammalian wildlife, baselines of exposure to mercury would have to be established. It would be expensive and logistically difficult to establish a baseline representing all human consumers of Clear Lake fish, and to determine a subpopulation which could then be tested periodically in the future. There are no representative data on hair or blood mercury concentrations for the United States population as a whole (USEPA, 1997b).

Analyses in feathers or eggs are well-established methods for evaluating exposure of birds to mercury (Burger and Gochfeld, 1997; Wolfe et al., 1998). Collection of feathers, particularly

those that have been molted, is a non-invasive process. Because the embryo is the most sensitive life stage to mercury, analysis of eggs of nesting birds provides a valuable tool for evaluating effects of mercury on reproduction of species at the top of the food web. Although measurements have been made of mercury in eggs and feathers of birds at Clear Lake (Elbert, 1996; Suchanek et al., 1997; Suchanek et al., 1993), we are lacking information needed to develop avian targets for Clear Lake. Threshold effect levels in feathers and eggs are not known for potential indicator species at Clear Lake, such as mergansers, grebes, herons or osprey. Thorough baseline information of existing levels of mercury in eggs of these birds at Clear Lake is also lacking. The U.S. Fish and Wildlife Service (USFWS) is currently conducting a CALFED-funded study on mercury dose and responses in avian species relevant to the San Francisco Bay and Delta, which may provide information applicable to Clear Lake.

## **Sediment**

The Central Valley Regional Board is not seeking to develop a target for mercury or methylmercury in sediment. Existing data from Clear Lake show poor correlations between concentration of mercury in sediment and levels of methylmercury in sediment or in the water column (McCalady et al., 2000; Suchanek et al., 1997). Sediment concentrations also do not correlate well with levels of mercury in fish or other aquatic organisms. Because of the lack of correlation between sediment levels and the amount of mercury found in biota and the lack of complete information about other sediment factors that regulate methylation, sediment is not recommended as a target compartment.

The mercury TMDL report for the San Francisco Bay Estuary proposes a target of total mercury in sediment for phase one of its TMDL (Abu-Saba and Tang, 2000)<sup>2</sup>. The proposed San Francisco Bay sediment target is based on the premise that mercury in San Francisco Bay should reflect the nature of sediment from the Central Valley, which is the main source of sediment entering the Bay. Underlying the rationale of the proposed sediment target is that for waterbodies in general, the concentration of total recoverable mercury in the water column is directly related to the amount of sediment suspended in the water. Sediments polluted from the mobilization of mercury during and after the Gold Rush are the primary reason that mercury in the water column exceeds the San Francisco Bay water quality objective. The San Francisco Bay Regional Water Quality Control Board has adopted a numeric water quality objective for mercury that applies to Bay waters north of the Dumbarton Bridge (25 ng/L total recoverable mercury). The California Toxics Rule (CTR) criterion applies to waters south of Dumbarton Bridge (50 ng/L total recoverable mercury; see Water section below). These water quality criteria are routinely exceeded in San Francisco Bay (Abu-Saba and Tang, 2000).

---

<sup>2</sup> The proposed sediment target for San Francisco Bay is 0.4 mg Hg/kg in sediment of particle size less than 63 microns. It is the median concentration of mercury in sediment samples collected from the mouth of the Sacramento River, normalized to the percentage of fine material in the sediment sample. Emphasis is placed on sediment size because there is a consistent, positive relationship between amount of fine material and mercury concentration.

Mercury concentrations in water and sediment have been characterized across the Bay using over eight years worth of water column and sediment monitoring data. Authors of the San Francisco Bay TMDL estimate that if mercury concentrations in sediment were at pre-anthropogenic levels, there would be few, if any, instances when the 25 ng/L objective would be exceeded. The Bay TMDL sediment target is higher than pre-mining levels. It was designed for the first phase of the TMDL in order to move closer to attainment of the Basin Plan objective. The San Francisco Bay sediment target addresses the largest, ongoing external sources of inorganic mercury entering the Bay. Lacking complete information about factors controlling methylation and sites of methylation, controlling mass loading of inorganic mercury is an appropriate place to start the TMDL process. The San Francisco Bay Regional Board proposes to develop targets for the second phase of the TMDL that more directly assess beneficial uses, namely fish tissue and avian egg targets appropriate to San Francisco Bay. Studies are ongoing to obtain the data needed for these targets.

## **Water**

Targets could be developed for four types of water measurements, total recoverable (unfiltered) or dissolved (filtered) levels for mercury and/or methylmercury. There are established criteria for total recoverable mercury that apply to Clear Lake, which protect humans consuming aquatic organisms and drinking water. The CTR criterion of 50 ng/L total recoverable mercury is intended to protect human health from non-cancerous effects of consuming contaminated organisms and drinking water from the same source (USEPA, 2000a). Mercury criteria for protection of aquatic life have not been promulgated in the CTR. The primary maximum contaminant level for mercury in drinking water, 2000 ng/L, is not exceeded in Clear Lake (Suchanek et al., 1997).

The CTR criterion for total recoverable mercury is exceeded in Clear Lake. Of water samples collected every six weeks to quarterly during May 1994 through August 1996, 25% (29/114) of deep water samples and 11% (13/114) of surface water samples contained mercury concentrations greater than 50 ng/L. Most samples with levels above 50 ng/L were collected from Oaks Arm, with only three samples coming from the Narrows, one from Lower Arm and none from Upper Arm. Mercury in water samples from Oaks Arm ranged up to 400 ng/L (Suchanek et al., 1997). A database of several hundred records for total mercury in water collected from 1992 to 1998 (including the above data) lists additional exceedances in Oaks Arm. Of the additional samples collected at the other locations, only one sample exceeded 50 ng/L; that sample was collected from Lower Arm (Suchanek, 2000).

The CTR criterion is unlikely to be sufficiently protective of humans consuming fish from Clear Lake. Bioaccumulation factors appear to be higher for the Clear Lake ecosystem (Suchanek et al., 1993), than the practical bioconcentration factors that were used to develop the CTR criterion. The USEPA anticipates revising the CTR to include the new methylmercury criterion in fish tissue. The Federal Register Notice of the CTR states that “EPA supports the use of new

information about bioaccumulation factors to develop site-specific criteria for mercury” (USEPA, 2000a).

Water column targets are not suggested as the primary target type for the Clear Lake TMDL. Total mercury in the water column is poorly correlated with levels of mercury in biota (Suchanek et al., 1993; Suchanek et al., 1997). The bulk of mercury measured as *total recoverable* is inorganic, particulate-bound mercury. Measurements of mercury largely unavailable to organisms are not functionally related to mercury levels in fish. Criteria for total recoverable or dissolved mercury do not specifically address methylmercury, which is the form of mercury that bioaccumulates in organisms. If the linkage between loads of various forms of inorganic and organic mercury and total methylmercury concentrations in fish cannot be made sufficiently robust for the TMDL with existing Clear Lake data, then the CTR value may be adopted as a secondary target for the Clear Lake TMDL. The correlation between dissolved mercury in the water column and mercury in biota of Clear Lake is slightly better than that for total recoverable mercury, but is still insufficient for the TMDL (Suchanek et al., 1997). The same lack of correlation between biota and water column measurements exists for total recoverable methylmercury in Clear Lake. Analysis of dissolved methylmercury in the water column may provide a closer measure of mercury that actually accumulates within organisms and biomagnifies in the food web.

Targets for mercury in water are one significant step removed from direct measurement of attainment of the beneficial use. To develop water column targets, a safe level of mercury in fish tissue is first determined, then the corresponding water column value is calculated using the following equation:

$$\text{Concentration of mercury in water} = \frac{\text{Concentration of mercury in fish}}{\text{Bioaccumulation factor}}$$

This method is used in the Mercury Study Report to Congress and in the Great Lakes Water Quality Initiative – Final Rule to derive water column criteria for inorganic and methylmercury (USEPA, 1995b; USEPA, 1997c). This method is also used in the draft San Francisco Bay TMDL report, which proposes a target for dissolved methylmercury (Abu-Saba and Tang, 2000). There is still considerable uncertainty in bioaccumulation factors, for both those that have been estimated using nationwide data (USEPA, 2001b) for those estimated using Clear Lake data (Suchanek et al., 1993). Regional Board staff proposes calculating site-specific bioaccumulation factors for the Clear Lake TMDL to link the target with necessary load reductions. The Regional Board has contracted with the UC Davis Clear Lake Environmental Research Center to provide bioaccumulation factors for Clear Lake.

**Key Points – Selection of Type of Target**

- Fish tissue is proposed as the primary target type. Levels of mercury in fish tissue directly indicate whether beneficial uses are being met. Data on mercury in fish from Clear Lake have been collected since 1970.
- Other potential target types are mercury levels in hair and blood of mammals, feathers and eggs of fish-eating birds, sediment, and water.
- Data on baselines and causes of variations of mercury levels in biota other than fish are currently lacking.
- Levels of mercury and methylmercury in sediment do not correlate well with levels of methylmercury in the water column and biota.
- The California Toxics Rule criterion for total recoverable mercury in water, 50 ng/L, does apply to Clear Lake. This criterion is exceeded in 10 to 25% of water samples collected in Clear Lake. The CTR value may be used as a secondary target for the TMDL.

## POTENTIAL HUMAN HEALTH TARGETS

The remainder of this document discusses development of fish tissue targets for humans and wildlife. In fish consumed by humans and wildlife species of concern, more than 90% of mercury is in the form of methylmercury, the most toxic form of mercury. Analyses of fish tissue typically measure total mercury, with the understanding that most of the mercury present is methylmercury. In the following discussions, *mercury* refers mainly to methylmercury. The linkage analysis portion of the upcoming TMDL Report will relate concentrations of methylmercury in biota to levels of inorganic mercury in the lake.

The Clear Lake mercury TMDL strategy seeks to reduce the risks to humans and wildlife of consuming fish from Clear Lake. Determining a final target for methylmercury in fish tissue to protect human health requires several decisions to be made. Key variables needed for the calculation of fish tissue targets are:

- acceptable daily dose level;
- age and body weight (bwt) of the consumer;
- fish consumption rate;
- trophic level or size of fish consumed, and
- portion size.

The relationship between these variables, and the options and recommendations for each variable, are discussed below.

## Fish Tissue Target Equation

The variables under consideration to develop a fish tissue target can be related using a basic equation (OEHHA, 2000; USEPA, 1995c). The equation is as follows:

$$\frac{\text{Safe daily intake} * \text{Consumer's body weight}}{\text{Consumption rate}} = \text{Acceptable level of mercury in fish tissue}$$

Units in this equation are:

$$\frac{\mu\text{g Hg /kg bwt/day} * \text{kg bwt}}{\text{g fish/day}} = \mu\text{g Hg / g fish (ppm)}$$

Where:

Hg = mercury

g = gram

μg = microgram

kg = kilogram

bwt = consumer's body weight

ppm = parts per million

The following is a sample calculation:

$$\frac{0.1 \mu\text{g/kg bwt/day} * 65 \text{ kg bwt}}{7.5 \text{ g fish/day}} = 0.86 \mu\text{g mercury/g fish, wet weight (0.86 ppm)}$$

Where:

Daily intake = 0.1 μg/kg bwt/day (USEPA's acceptable daily intake level)

Consumer's body weight = 65 kg (adult)

Consumption rate = 7.5 g fish/day (one 8 oz fish meal per month)

As shown by this equation, consumption rate can make a marked difference in the calculated fish tissue concentration. In the example above, for an adult eating one fish meal each month, the acceptable level of mercury in fish consumed is 0.86 ppm or less. For an adult eating four fish meals each month, the acceptable fish tissue level drops to 0.2 ppm.

In calculation of its methylmercury criterion to protect human health, USEPA added one additional component to the equation (USEPA, 2001b). In applying a numeric target to a particular waterbody, the goal of the target is to protect consumers of fish from that waterbody. Humans are exposed to mercury from commercial and marine fish as well as locally caught fish. Consumption surveys indicate that, on average, between 25 and 30% of methylmercury comes from marine fish. Human intakes of methylmercury from all other media sources (air, drinking water, soil, and foods other than fish) are considered negligible. In calculating the methylmercury criterion, the USEPA methodology estimates the degree of exposure through routes other than consumption of local fish as a relative source contribution (RSC). The RSC represents that portion of methylmercury exposure that will not be controlled by cleanup actions directed to a particular waterbody. Because fish at different levels of the food web contain varying amounts of mercury,

the consumption rate can be separated into rates of consumption at each trophic level. The adjusted equation appears as:

*Equation 1*

$$\frac{(\text{Safe intake} - \text{intake from other sources}) * \text{body weight}}{(\text{CRate}_{\text{TL2}} + \text{CRate}_{\text{TL3}} + \text{CRate}_{\text{TL4}})} = \text{Acceptable level of mercury in fish}$$

Where:  $\text{CRate}_{\text{TL2}}$  = consumption rate of fish from Trophic Level 2

This equation is used to develop the numeric target for Clear Lake. In order to illustrate better the reductions needed at Clear Lake, this report compares the estimated mercury intake due to existing conditions with the safe daily intake level of mercury. This comparison is done for both humans (Table 7) and wildlife (Table 12). Estimated mercury intake by consumers of Clear Lake fish is calculated by rearranging the above equation to solve for methylmercury intake.

*Equation 2*

$$\frac{(\text{CRate}_{\text{TL2}} * \text{Fish}_{\text{TL2}}) + (\text{CRate}_{\text{TL3}} * \text{Fish}_{\text{TL3}}) + (\text{CRate}_{\text{TL4}} * \text{Fish}_{\text{TL4}})}{\text{Body weight}} = \text{Intake of methylmercury from Clear Lake fish}$$

Where:  $\text{CRate}_{\text{TL2}}$  = consumption rate of fish from trophic level 2

$\text{Fish}_{\text{TL2}}$  = concentration of methylmercury in fish from trophic level 2.

### Acceptable Daily Intake Level – Options

The first variable to be reviewed is the acceptable daily intake level of methylmercury. The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. To people not exposed to mercury in a workplace, ingestion of seafood containing methylmercury is by far the most significant route of exposure (USEPA, 1997d). Intake levels generally describe the acceptable dose relative to the consumer's body weight. Acceptable intake levels, or reference doses (RfD), have been developed by several national and international agencies.

Reference doses are expressed as a daily rate (micrograms of mercury per kilogram body weight per day) of mercury intake. In general, reference doses are calculated by using studies of exposure in specific populations to determine a threshold level of exposure, below which adverse effects did not occur. The threshold level is then divided by uncertainty factors that lower the threshold level to the final reference dose. Uncertainty factors incorporate the uncertainty in defining a threshold value that is applicable to the entire population. Uncertainty factors account for differences in metabolism and sensitivity between individuals, lack of toxicity information in available studies, or other unknowns. Reference doses for wildlife are derived similarly. Wildlife RfDs may include uncertainty factors for extrapolating data from one species to another.



Methylmercury intake levels are based on studies of humans exposed to methylmercury in the diet. There were mass poisoning episodes resulting in many fatalities in Minamata and Niigata, Japan in the 1950s and 1960s due to consumption of fish from waters into which methylmercury was discharged from industrial sources (Tsubaki and Irukayama, 1977). Famines in 1971 and 1973 forced Iraqi people to eat seed grain that was treated with methylmercury fungicide, which resulted in fatalities and lesser effects (Bakir et al., 1973). Studies of these situations conclusively linked methylmercury exposure to neurological disease and death and demonstrated severe effects in infants born of mothers whom themselves had few symptoms of methylmercury poisoning. More recently, long-term cohort studies have been conducted with inhabitants of the Faroe Islands (Grandjean et al., 1997) and Seychelles Islands (Davidson et al., 1998). Newer studies of mercury consumption are tracking relatively subtle effects on fine motor control, memory and audio-visual functions. Peoples of the Faroe and Seychelles Islands are chronically exposed to methylmercury through seafood in their diets. These studies evaluated exposure during pregnancy and are continuing to measure development throughout childhood.

Recommended safe intake levels have evolved as information on toxic effects and sensitive subpopulations has become available. The USEPA and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) have developed consumption limits specifically designed to protect unborn children from mercury consumed by their mothers. The USEPA published a RfD of 0.1  $\mu\text{g}$  methylmercury/kg bwt/day in 2000. The ATSDR Minimal Risk Level (MRL) issued is 0.3  $\mu\text{g}$ /kg bwt/day (ATSDR, 1999). In 1998, Health Canada released its daily intake level to protect fetuses of 0.2  $\mu\text{g}$ /kg bwt/day (Mahaffey, 1999). These intake values to protect the unborn were derived from studies that correlated methylmercury dose consumed by the mother with adverse neurological effects or delayed development in their young children. Although the USEPA RfD and the ATSDR MRL are presented as daily intakes for adults, the levels were calculated to prevent extra risk (i.e., above background levels of risk) of neurological damage to infants during gestation.

ATSDR describes an MRL as “an estimate of daily human exposure to a dose of a chemical that is likely to be without an appreciable risk of adverse noncancerous effects”. It is conceptually equivalent to an RfD (ATSDR, 1999). ATSDR developed its MRL for mercury from a study of mother-child pairs in the Seychelles Islands. Data from the Seychelles study were used to calculate an MRL for mercury based upon determination of a no-observed adverse effects level for the most sensitive subpopulation, children exposed *in utero*. The ATSDR used data from evaluations of children using age-appropriate neurodevelopmental, memory and physical ability tests at 66 months of age to calculate an MRL (Davidson et al, 1998). Maternal exposures were not measured directly, but instead were estimated from maternal hair levels during pregnancy. Because the results of the tests conducted at 66 months showed no adverse effects, the mean

maternal hair concentration of mercury (15.3 ppm<sup>3</sup>) in the group with the highest exposure was considered the no-observed effect level. ATSDR applied an uncertainty factor of three to incorporate variability in methylmercury absorption and metabolism, and a factor of 1.5 to account for the possibility that an unknown factor specific to the Seychelles experience contributed to the lack of adverse effects. The final MRL issued in 1999 is 0.3 µg/kg/bwt/day. Derivation of the MRL is discussed in greater detail in the Sacramento River Watershed Program's Report of Candidate Targets for Mercury (SRWP, 1999).

The USEPA recently revised its methylmercury reference dose. The preliminary draft version of this Numeric Target Report discussed the reference dose that the USEPA established in 1995. The 1995 RfD was based upon a study of children in Iraq that examined associations between neurologic impairments in children with estimates of methylmercury intake by their mothers during pregnancy (Marsh et al., 1987). Exposure to the mothers was through consumption of contaminated seed grain. For the calculation of the 1995 RfD, the benchmark dose level was 11 mg/g mercury in maternal hair and the uncertainty factor was 10. After release of the TMDL draft Numeric Target Report, the USEPA issued a revised RfD for methylmercury in December 2000. The 2000 RfD is the same value as the 1995 RfD, 0.1 µg methylmercury/kg bwt/day, but is based on the more recent studies and reevaluation of data (USEPA, 2001b).

One disadvantage of the 1995 USEPA RfD was that the Iraq situation of high concentrations of methylmercury in bread consumed over a short period of time is a different exposure pattern than chronic consumption of relatively low methylmercury levels that is expected for populations of concern for the TMDL. Mercury received in a consistent, low-dose exposure regimen could result in effects less severe than the same amount of mercury taken in over a shorter time period. Another concern with the 1995 USEPA RfD arose around uncertainties in the underlying study. Lacking Western-style medical records, dating and quantification of effects in children were based in part on parental recall of developmental and behavioral milestones.

In June 2000, the National Research Council (NRC) of the National Academy of Sciences released its guidance to USEPA on development of an RfD (NRC, 2000). The NRC was asked by the U.S. Congress to evaluate the body of data on the health effects of methylmercury, and to provide recommendations regarding data and methodology most appropriate for determining an RfD. The NRC committee was not asked to derive an RfD *per se*. The NRC committee conducted a comprehensive review of data and reports regarding health effects of exposure to methylmercury. The NRC committee determined that the Iraq study by Marsh and colleagues, because of uncertainties and differences in exposure routes, should no longer be considered the critical study for the derivation of the RfD. The NRC compared designs and results of studies in the Faroe Islands, Seychelles Islands and New Zealand, and concluded that the Faroe Islands study is the most appropriate for deriving an RfD. NRC identified a benchmark dose level of 58 µg/L mercury

---

<sup>3</sup> ppm = part per million. For mercury in hair, units of ppm are µg mercury /g hair. In this report, "ppm" is also used as a unit for mercury in fish tissue, equivalent to µg mercury/g fish tissue.

in umbilical cord blood, which corresponds to a benchmark of 12 ppm mercury in maternal hair. NRC also recommended a composite uncertainty factor of 10, to account for variation between humans and to account for data gaps relating to possible long-term neurological effects not evident in childhood, as well as possible effects on the cardiovascular and immune systems. On the basis of its evaluation of newer mercury exposure data, the NRC committee concluded that a reference dose of 0.1 µg/kg bwt/day is a scientifically appropriate level for the protection of public health.

The USEPA revised its RfD after considering the recommendations of the NRC committee and comments made by peer reviewers. The study selected by the USEPA as the basis of the 2000 RfD is the report of developmental neurotoxicity in seven-year old children in the Faroe Islands (Grandjean et al., 1997). The benchmark dose level is based upon results of several tests of neuropsychological function. A composite uncertainty factor of 10 was incorporated, for a final RfD of 0.1 µg/kg bwt/day. The final report describing the revised 2000 RfD was published as the fourth chapter in the methylmercury water quality criterion (USEPA, 2001b). One important point should be noted regarding applicability of the revised USEPA RfD to the general population. According to the USEPA,

“In the studies so far published on subtle neuropsychological effects in children, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling. That is, there are currently no data that would support the derivation of a child (versus general population) RfD. This RfD is applicable to lifetime daily exposure for all populations including sensitive subgroups. It is not a developmental RfD per se, and its use is not restricted to pregnancy or developmental periods.” *Water Quality Criterion for Methylmercury, Section 4-6*, (USEPA, 2001b)

The daily intake levels described above were calculated to represent “safe” levels of mercury intake for the age range for which the level is intended. The USEPA describes its RfD as an estimate of a daily exposure level to humans that is likely to be without an appreciable risk of deleterious effect during a lifetime. Mercury exposure at or below the USEPA RfD, for example, is not expected to cause any increase above the background level of risk for adverse outcomes in fetuses, children or adults.

Other daily intake limits have been developed that protect from adverse effects of methylmercury exposure only in adults. The U.S. Food and Drug Administration (USFDA) and the World Health Organization (WHO) each set consumption limits that were designed to protect adults. Adults in the Iraq poisoning incidents were evaluated for development of paresthesia (an abnormal “prickling” sensation in the skin), which is an early clinical symptom of neurological damage. The physiological threshold for neurological deficits in adults is higher than for infants and children. As a result, intake limits designed to protect only adults are higher than those created to protect the unborn. The USFDA set an action level of 1.0 ppm mercury in fish tissue, wet weight, in 1979. The tolerable level associated with USFDA action level is approximately 0.47 µg/kg

bwt/day. In 1990, the WHO set a level to protect adults of 0.48 µg/kg bwt/day. Both the USFDA and WHO have acknowledged that fetuses may be more sensitive than adults to effects of mercury. The USFDA recommends that pregnant women and children limit their intake of fish species known to contain high levels of mercury (Toffleson and Cordle, 1986; WHO, 1990).

### **Acceptable Daily Intake Level – Recommendations**

Data collected to date demonstrate that neural development of a fetus during pregnancy is the most sensitive human life stage to toxic effects of methylmercury. To be fully protective of human health, therefore, a mercury dose level should protect this most sensitive age. Of the mercury dose levels established by various United States entities, the USEPA reference dose and the ATSDR minimal risk level were clearly calculated to be safe levels for pregnant women and unborn children.

The USEPA's 2000 RfD appears to be the intake level most consistent with protecting the beneficial uses in Clear Lake. The methodologies for deriving the RfD, underlying studies, benchmark dose and uncertainty factor were evaluated thoroughly by the panel of the NRC, by USEPA scientists and by peer reviewers of the revised USEPA RfD. These groups collectively supported use of the Faroe Islands study as the basis of the RfD, similar benchmark dose levels and the same uncertainty factor value.

Use of the USEPA RfD provides consistency within State of California agencies. Within the Central Valley, the Office of Environmental Health Hazard Assessment (OEHHA) is the state-level agency charged with evaluating risks to public health of environmental contaminants. OEHHA scientists have also been in the process of evaluating recent methylmercury studies and reference dose options. The OEHHA is currently using the USEPA RfD for its risk assessments of methylmercury exposure *via* sport fish consumption (OEHHA, 2000) (see also Appendix C, Response to Comments).

A common criticism of the Faroe Island study is that whale meat consumed by participants contains polychlorinated biphenyls (PCBs) as well as methylmercury. PCBs are known to have adverse neuropsychological effects, as measured in some of the same tests administered to children in the mercury studies. The potential for PCBs to contribute to adverse effects seen in the Faroe Islands children was thoroughly evaluated, by the authors of the study and by the NRC panel. Both groups concluded that the associations between mercury and adverse effects in children were real, and were not attributable to the confounding by prenatal PCB exposure (NRC, 2000; USEPA, 2001).

The USEPA RfD relieves at least partial concern about effects of mercury exposure during key time points of gestation. It is likely that there are time periods during gestation during which neural development of the fetus is particularly sensitive to mercury toxicity. There are concerns that short-term “spike” exposures during pregnancy could have significant adverse effects on the

developing infant (Mahaffey, 1999). Medical studies have not yet identified periods of sensitivity. The study on which the USEPA RfD is based did encompass some intermittent, spiked doses during pregnancy. The Faroe Island study participants reported an intermittent exposure pattern (1 to 3 meals/week) with occasional meals of pilot whale, which has higher concentrations of mercury than the fish. Multiple segments of hair from some mothers indicated spikes in intake, although within individuals, peak concentrations were only twice the lowest hair mercury concentrations. In the report of the methylmercury RfD, USEPA authors suggest that the episodic consumption pattern of the Faroe Islands population may better represent the pattern of exposure in the majority of the United States population, than does the consumption pattern in the Seychelles (USEPA, 2001b). During implementation of the TMDL, it seems clear that efforts should be substantially increased to educate female consumers on the potential risks during pregnancy.

Uncertainty factors in the recommended RfD provide a margin of safety for the final TMDL target. In calculation of its RfD, the USEPA incorporated a ten-fold uncertainty factor to account for individual variation. The NRC committee supported the 10-fold uncertainty factor. Incorporation of the uncertainty factor lowers the acceptable daily intake level ten times below the benchmark level at which adverse effects are expected.

Regional Board staff does not recommend use of the ATSDR intake value. The ATSDR MRL for mercury was drafted in 1997 and finalized in March 1999, prior to completion of the NRC committee report. The basis of the ATSDR MRL was the Seychelles Islands study, which showed no correlation between mercury and adverse neurodevelopmental effects. In contrast, the Faroe Islands study showed adverse outcomes associated with mercury exposure. A smaller study in New Zealand used a research design and described a pattern of exposure similar to the Seychelles study, but reported associations with mercury that were similar to those found in the Faroe Islands. The NRC committee concluded that "...because there is a large body of scientific evidence showing adverse neurodevelopmental effects, including well-designed epidemiological studies, an RfD should not be derived from a study, such as the Seychelles study, that did not observe any associations with methylmercury" (NRC, 2000). The ATSDR MRL has not been revised or updated since the NRC report was released.

There is an additional reason the ATSDR number was not selected as the preferred RfD for the mercury target. ATSDR MRLs, which are intended to serve as screening levels, are used by ATSDR to identify contaminants and potential health effects that may be of concern at hazardous waste sites. According to ATSDR, "... MRLs are not intended to define clean-up or action levels for ATSDR or other Agencies" (ATSDR, 1999).

Regional Board staff acknowledges that scientific debate remains regarding the study or endpoints most appropriate for use as a basis of an RfD. New data will likely be available after testing of the Faroe and Seychelles Islands children beyond seven years of age, and possibly from new epidemiology studies, as well. The OEHHA is continuing its evaluation of the data and has not yet

officially adopted an RfD for methylmercury. Regional Board staff will continue to review new mercury data and evaluations by the OEHHHA, USEPA and other agencies. Should conclusions or available reference doses change, the Regional Board may reconsider its target selection.

#### **Key Points – Calculation of Fish Tissue Target and Selection of Human Health Reference Dose**

- A fish tissue target must be calculated to protect human health. Children during gestation and in their earliest years are most sensitive to the toxic effects of mercury.
- Key variables needed for the calculation of fish tissue targets are: an acceptable daily dose level (reference dose), age and body weight of the consumer, fish consumption rate, and portion size. These variables are related in the following equation:

$$\frac{\text{Safe daily intake} * \text{Consumer's body weight}}{\text{Consumption rate}} = \text{Level of mercury in fish tissue}$$

- The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. Daily intakes are reported as the amount of mercury safely consumed relative to the consumer's body weight.
- Of the various acceptable daily intake values determined by different agencies, only those released by the USEPA (0.1 µg/kg bwt/day) and the ATSDR (0.3 µg/kg bwt/day) are calculated to fully protect unborn children.
- The USEPA RfD released in December 2000 is based upon adverse effects of mercury in children from the Faroe Islands. In a comprehensive review of the literature, a NRC panel recently recommended a benchmark dose level and uncertainty factors that result in an RfD of 0.1 µg/kg bwt/day. The revision of the USEPA RfD was guided significantly by the NRC conclusions.
- The USEPA RfD of 0.1 µg/kg bwt/day appears to be the intake level most consistent with protecting the beneficial uses in Clear Lake.

#### **Body Weight and Portion Size – Options**

The previous section described selection of an acceptable daily intake of methylmercury to protect human health. In setting a fish tissue target that will not cause consumers to exceed the RfD, variables pertaining to the consumer must be incorporated into the target value. Three necessary values are fish portion size, consumption rate and consumer body weight.

The USEPA has stated, based on its review of fish consumption studies, that the most commonly reported seafood portion size was eight ounces (227 g) (USEPA, 1995c). A review by the OEHHHA of consumption studies found that single serving sizes of seafood consumed by adults usually ranged from four to eight ounces; one study found an average portion size of eleven ounces eaten by coastal fishers in New Jersey (Gassel et al., 1997).

The USEPA uses standard bodyweights of 60 kg for an average adult female and 70 to 72 kg for an average adult man. Bodyweights of 65 to 67 kg have been used as average measures of a

pregnant adult woman. Children's bodyweights and smaller portion sizes can also be fitted into the equation above. The OEHHA has published a table of sizes of typical fish meals that correspond to smaller bodyweights (OEHHA, 1999).

### **Body Weight and Portion Size – Recommendation**

Regional Board staff used the standard portion size of eight ounces for the TMDL numeric target. There is limited data on serving sizes for consumers of freshwater or marine sport fish in California. Any new studies of sport fish consumption from a Central Valley region or specific waterbody should collect information about portion size.

For the TMDL target, Regional Board staff used the USEPA's standard pregnant adult bodyweight (65 kg) to best ensure that a mercury target protects unborn children. Using the USEPA's RfD for the TMDL target does protect unborn and all children, even though the RfD is expressed as acceptable daily exposure for adults. Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size. A table, such as that created by the OEHHA, could be used to adjust the target for the smaller bodyweight or portion size of children (OEHHA, 1999).

### **Consumption Rate – Options**

The fourth variable needed to determine a fish tissue target is the consumption patterns for people eating fish from Clear Lake. Consumption rate is the most difficult of the fish tissue target variables to define. The amount of methylmercury ingested is highly dependent on the amount of fish and the sizes and species of fish consumed. Ideally, a fish tissue target for Clear Lake would be based upon actual patterns of consumption of fish from Clear Lake. One consumption study has been completed for members of the Elem Pomo Tribe and some non-tribal neighbors (Harnly et al., 1997), but data for others eating Clear Lake fish have not been collected. It is necessary then, to examine national and other localized seafood consumption studies. A number of these have been conducted regionally and nationwide. OEHHA has published a comprehensive review and evaluation of these studies (Gassel et al., 1997). Results of fish consumption surveys are also compiled in the Mercury Report to Congress (USEPA, 1997d). The following summary of fish consumption studies is derived primarily from the OEHHA report. A variety of consumption rates, including those recommended for consideration in preparing a fish tissue target, is presented in Table 3. Discussions of mercury concentrations in local and commercial fish and consumption of fish from various trophic levels follows.

Identification of a consumption rate is complex, not only because of the variety of consumption studies, but because the target consumption rate involves policy as well as scientific decisions. The consumption rates outlined below describe the consumption patterns of a particular group or "average" consumer. Selecting the consumption rate also selects the consumption patterns or

groups. The consumption patterns that are protected by the target are, in part, a risk management decision.

A purpose of the TMDL target is to set a level of mercury in fish that is safe for human consumption. The Clean Water Act requires that waters be maintained such that they are fishable and swimmable. The Clean Water Act does not clarify the meaning of “fishable”. Restoring the beneficial use of sport fishing requires that the Regional Board identify the desired amount of fish that could be caught from Clear Lake and safely consumed per person. Phrased differently, the TMDL seeks to determine a functional definition of what it means for Clear Lake to be “fishable”.

The desired level of fishing and consuming from Clear Lake lies somewhere between the limited amount recommended in the existing fish advisory and a probable upper bound of a very high consumer (i.e., the 99th percentile in United States consumption studies). Unless the mercury concentration was reduced to zero, people who eat unlimited quantities of fish from Clear Lake would undoubtedly incur a health risk. Additionally, for many consumers of Clear Lake fish, the lake is not the only source of fish eaten. Because of global mercury pollution, ocean fish also contain mercury. Consumers eating more than one meal of canned tuna per week can exceed the safe intake level of methylmercury.

Beneficial use protection in the case of mercury pollution, therefore, must be accomplished by a combination of cleanup and education. Education is needed as part of a TMDL Implementation Plan until effects of all mercury reduction efforts are reflected in fish tissue levels. While TMDL targets may be reached on average in top trophic level fish, it is possible that mercury concentrations in very large catfish or largemouth bass from Clear Lake (now 1.5 ppm wet weight or more) may never be reduced sufficiently to be safe for human consumption. Education may need to continue to encourage consumers to eat smaller fish and species with lower mercury concentrations.

The definition of *sport fish* includes any seafood not obtained at a commercial market, caught by self or family member by recreational means. With respect to consumption rates in the following text, *fish* is used interchangeably with *seafood* to include any bony fish, shark, or shellfish eaten.

Fish consumption data are generally reported in one of two ways. *Per capita* values indicate fish consumption by an entire study population, including those that do not eat seafood. *Consumer-only* rates indicate consumption patterns for portions of the general population that consume sport and/or commercial seafood. Per capita rates are available from nationwide diet surveys conducted by U.S. Department of Agriculture (USDA). Mean consumption rates expressed per capita from these studies for all men, women and children range from 6.5 to 18 g fish consumed per day (Gassel et al., 1997). Per capita rates are useful for market trend analyses but are not as relevant for deriving water quality criteria. Water quality criteria are designed to protect users of aquatic resources. Consumption rates used for developing criteria, therefore, should describe intake only for those that consume seafood.



### *National Consumption Surveys*

The USDA conducted surveys collecting fish consumption information from across the country as part of their surveys of all food products and by national surveys specifically targeting seafood consumption. Results from national surveys are generally reported as per capita. Data from only a few national surveys have been analyzed to provide consumer-only rates. Using data from the 1977-78 Nationwide Food Consumption Survey, Pao and colleagues reported an overall average rate for consumers of 48 g/day (Pao et al., in Gassel et al., 1997). The per capita rate for the same data was 12 g/day. Pao and colleagues derived mean rates of 44 g/day and 49 g/day for women consumers only, aged 19-34 and 35-64 years, respectively. Using the same data, Popkin and colleagues determined the average consumption rate for women aged 19-50 years was 111 g/day (Popkin et al., 1989). Popkin and colleagues estimated the amount of fish and seafood consumed in mixed dishes, such as seafood salad, casserole or chowder. Pao and colleagues analyzed the same national surveys but did not estimate consumption from mixed dishes. This analytical issue is discussed further below. Data from the USDA 1994-96 Continuing Survey of Food Intake by Individuals (CFSII 1994-96) was analyzed and used by USEPA to develop its default consumption rates for human health criteria (USEPA, 2000b).

Several rates for consumers-only nationwide, for all consumers, and for women of child-bearing age are shown in Table 3. There are no national surveys aimed at sport fishers or that separate sport and commercial fish consumption. Some consumer-only nationwide rates have been derived through reanalysis of national food consumption surveys. Evaluations of nationwide consumption information can produce widely varying results, depending upon the study population, types of fish meal (fish only or including “mixed” dishes like tuna casserole and chowder), and the survey methodology (single-day recall or month-long recall). Incorporation of mixed dishes results in a higher consumption rate, but reliability of the results depends upon how accurately the portions of fish in mixed dishes were estimated. Consumption rates based upon recall periods of a month or more tend to be lower than rates based on intake over periods over less than one week (Gassel et al., 1997; USEPA 1997b).

Table 3. Seafood Consumption Rates

Site and Dates Collected	Data Type	Fish Consumption Rate (g/day)	Reference	Comment (Identifies whether rate is for locally-caught (LOCAL), COMMERCIAL seafood, or BOTH.)	Equivalent Meals per Month (a)
Santa Monica Bay Data reported for recent consumers only (ate local fish at least once in 4 weeks prior to interview).	median	21	SCCWRP and MCB Appl. Env. Sci, 1994; Allen et al., 1996, in: Gassel et al., 1997	LOCAL Interviewed fishers on site.	2.8
	mean	50			6.7
	90 <sup>th</sup> percentile	107			14.3
	95 <sup>th</sup> percentile	161			21.5
San Francisco Bay Data reported for recent consumers only (ate local fish at least once in 4 weeks prior to interview).	median	16	SFEI, 2001	LOCAL Interviewed fishers on site. Data adjusted for avidity bias.	2
	mean	23			3
	90 <sup>th</sup> percentile	48			6.4
	95 <sup>th</sup> percentile	80			11
Elem Pomo Tribe and non-tribal neighbors, 1992	90 <sup>th</sup> percentile of participants (75 <sup>th</sup> percentile of consumers only).	30	Harnly et al., 1997	LOCAL	4
Nationwide mean rate for adult consumers only	mean	48	Pao et al., 1982, in: Gassel et al., 1997	BOTH Data from USDA 1977-78 Nationwide Food Consumption Survey, does not include mixed dishes.	6.4
U.S. women ages 19-50 for consumers only, 1977-78	mean	111	Popkin et al., 1989	BOTH Data from USDA 1977-78 Nationwide Food Consumption Survey, includes estimation of mixed dishes.	15
U.S. women ages 19-64 for consumers only, 1977-78	mean	44-49	Pao et al., 1982, in: Gassel et al., 1997	BOTH Data from USDA 1977-78 Nationwide Food Consumption Survey, does not include mixed dishes.	6
U.S. Women ages 19-44 for consumers only, mid 1990s	50 <sup>th</sup> percentile	9	USEPA, 1997b	BOTH Data from National Health and Nutrition Examination Survey, month-long recall	1
	90 <sup>th</sup> percentile	46			6
Michigan Statewide Survey, Jan. - June 1988	mean	45	Murray and Burmaster, 1994, in: Gassel et al., 1997	BOTH Mail survey of sport fish license holders. Rate for consumers only	6

Table 3. Seafood Consumption Rates

Site and Dates Collected	Data Type	Fish Consumption Rate (g/day)	Reference	Comment (Identifies whether rate is for locally-caught (LOCAL), COMMERCIAL seafood, or BOTH.)	Equivalent Meals per Month (a)
Michigan Statewide Survey, Jan. - June 1988	mean	18	West et al., 1992, in: Gassel et al., 1997	BOTH Mail survey of sport fish license holders. Rate includes non-consumers	2.4
USEPA, Ambient Water Quality Criteria, 1980	default rate for general population	6.5	USEPA, 1980	BOTH per capita rate for non-marine species only, using early 1970s consumption data	0.87
USEPA, revised Ambient Water Quality Criteria Methodology, 2000	default rate for general population (90 <sup>th</sup> percentile of all respondents)	17.5	USEPA, 2000b	FRESH/ESTUARINE (b) Rates based on USDA 1994-96 Continuing Survey of Food Intake by Individuals.	2.3
	default rate for subsistence fishers	142.2		FRESH/ESTUARINE	19
	default rate for recreational fishers	17.5		FRESH/ESTUARINE	2.3
	rate for average consumer (mean intake of marine species by all respondents)	12.5		COMMERCIAL	1.7

(a) Equivalent meals per month calculated for a 70 kg person eating 8 oz seafood portions.

(b) Freshwater/estuarine consumption rates are equivalent to locally-caught or sport fish consumption rates.

## Local Consumption Data

One study of mercury exposure that includes consumption of Clear Lake sport fish has been completed (Harnly et al., 1997). In November 1992, Harnly and colleagues interviewed 63 Members of the Elem Pomo Tribe and five non-tribal neighbors of the Elem Rancheria. Study participants recalled the frequency, species and sources of seafood they had eaten in the previous six months. Consumers of Clear Lake fish had an average consumption rate of 60 grams of fish/day. However, only six adults (10% of study participants, 26% of those who ate Clear Lake fish) reported an intake greater than 30 g/day, indicating that average consumption rates were influenced by high consumption rates of a few individuals. As estimated from graphics in the published paper, the highest consumption rate of Clear Lake fish was 350 g/day. Thirty-two persons reported eating an average of 24 g/day of commercial seafood. Total consumption rates and portion sizes for study participants eating both commercial and sport fish were not reported. Results of this study are reported in Tables 4 and 6 and in Appendix B, and are discussed in more detail in later sections. Note that this study was conducted after the fish consumption advisory for Clear Lake was issued. Traditional consumption rates would presumably have been higher.

Table 4. Consumption of Clear Lake Fish by Members of the Elem Pomo Tribe and Non-tribal Neighbors.

	Average Consumption [# of Consumers] (a) (g/day)
Catfish (b)	53 [19]
hitch	12 [4]
largemouth bass near Elem Rancheria	5 [2]
carp	1 [1]
perch (c)	74 [4]
Average consumption, all Clear Lake fish (d)	60 [23]
90 <sup>th</sup> percentile of study participants	30 [68 participants]

(a) Consumption reported for six month period (Harnly et al., 1997).

(b) White catfish and channel catfish can be caught in Clear Lake.

(c) Exact species described as "perch" are unknown. Based upon fish available and observations of fishers in Clear Lake, the category of "perch" most likely refers to bluegill and other sunfishes, white crappie and black crappie (Cannata, 2000). Native Sacramento perch were rare in Clear Lake in the early 1970s, but populations may be increasing (Macedo, 1991). Sacramento perch comprised about 1% of the catch by recreational fishers, as reported in a Department of Fish and Game creel survey of anglers conducted in 1988. The estimated methylmercury in fish tissue used in the table is the average of concentrations in crappie (Stratton et al., 1987).

(d) The average consumption is higher than the 90<sup>th</sup> percentile. Averages are driven up by consumption rates of a few, high consuming individuals. Distributions of consumption rates for each fish species were unavailable.

### *Regional Consumption Data*

One method of gathering sport fish consumption information is through personal interviews, either at a central location (used for recording fish-eating habits of some Native American tribes) or on-site interviews conducted at fishing locations, including shoreline, piers and boat docks. Patterns of consumption of locally caught sport fish were studied for a wide demographic of anglers in Santa Monica Bay (Southern California Coastal Water Research Project et al., 1994; Allen et al., 1996 in: Gassel et al., 1997). Anglers were asked about their consumption of eight commonly caught species plus fish in hand. Interviews were conducted in five languages, twelve times per month during the summer and six times per month otherwise, for one year, 1991-1992. An extensive survey of anglers in San Francisco Bay utilizing similar reporting methods was conducted in 1998-1999 (SFEI, 2001).

The Santa Monica Bay and San Francisco Bay seafood consumption surveys are the best available datasets for estimating sport fish consumption rates among California fishers. Data from these studies are shown in Table 3. For both studies, data is shown for recent consumers, identified as anglers who had eaten local fish during four weeks prior to the interview. Fish consumption rates were higher in Santa Monica Bay than in San Francisco Bay. Differences in consumption rates may be due to differences in demographics of the angler populations, productivity of the fisheries, weather, or other factors. Authors of the San Francisco Bay study also note differences in data collection and analyses that may have contributed to the variance in results. How frequently an angler goes fishing (avidity) influences how likely it is that the angler will be interviewed. San Francisco Bay data were adjusted for avidity bias in order to better characterize fishing by the overall angler population. When reanalyzed to adjust for avidity bias, the mean consumption rate of recent consumers in Santa Monica Bay is 30 g/day.

Several other, less extensive interview-type surveys of anglers have been conducted in California. Sport anglers in the Los Angeles metropolitan area, which encompasses Santa Monica Bay, were asked about consumption of their catch by themselves and their families during interviews conducted throughout 1980. Interviews were conducted only in English. The Los Angeles Metropolitan Survey reported the median amount of sport fish and/or shellfish consumed was 37 g/day and the 90<sup>th</sup> percentile was 225 g/day (Puffer et. al. 1982, in Gassel et al., 1997). The San Diego County Department of Health Services (SDCDHS) conducted interviews at popular fishing locations in San Diego Bay. An average consumption rate of 31 g/day was reported for the small number of anglers (population size [N] = 59) for whom year-round consumption data were available (SDCDHS, 1990 in Gassel et al., 1997). A small survey conducted in 1993 by the Save San Francisco Bay Association (Wong, 1997 in: Gassel et al., 1997), reported a median consumption rate of sport fish and/or shellfish of 32 g/day. The OEHHA review noted that the sample size was small (N = 62) and survey sites were not randomly selected for the San Francisco Bay study.

### *Other Sport and Locally Caught Fish Consumption Data*

One method of collecting sport fish consumption data is through surveys sent to licensed sport anglers. The 1988 Michigan Statewide Survey is one of the most comprehensive mail surveys of sport fish license holders and their families (West et al., 1992; Murray and Burmaster, 1994 in: Gassel et al., 1997). Surveys sent between January and June 1988 asked respondents to report consumption during a seven-day recall period. From the 1988 Michigan survey data, West and colleagues reported an overall mean rate of sport fish consumption by all ages of 18.3 g/day. In their calculations, West and colleagues included all ages and respondents, including those who did not consume fish during the study period. Murray and Burmaster analyzed the same raw data and calculated a mean rate of 45.3 g/day for adults who consumed fish during the study period. Both rates represent consumption of commercial and sport fish. Other mail surveys of anglers have reported the following consumption rates for commercial plus sport fish:

- Michigan 1991-92 survey: 45 g/day average consumption;
- New York 1988 survey: 28 g/day average consumption; and
- Wisconsin 1985 survey: 28 g/day average consumption, 64 g/day for the 95<sup>th</sup> percentile.

The average quantity of commercial fish eaten in addition to catches of sport fish was 10 g/day, as reported in an analysis of the Michigan Statewide Survey (Murray and Burmaster, 1994). Other studies showed consumers ate a range from 8 to 20 g/day of commercial fish in addition to sport fish (Gassel et al., 1997).

The actual intake of mercury from seafood by participants in the Seychelles or Faroe Islands studies is difficult to estimate. Measurements of mercury in maternal hair and blood, and/or umbilical cord blood were taken to assess exposure of participants in the Seychelles and Faroe Islands studies. Neither study was designed to obtain detailed information on diet. Mothers in the Seychelles Child Development Study reported consuming an average of 12 fish meals a week during pregnancy (OSTP, 1998). Ocean fish consumed by the Seychelloise have an average methylmercury concentration of less than 0.3 ppm wet weight. Faroese adults reported eating fish for one to three dinners per week (average 72 g/day) and pilot whale occasionally (OSTP, 1998). Because portion sizes were not reported for either study, estimates of mercury intake would be uncertain.

It should be emphasized that levels of mercury in fish from Clear Lake are not expected to cause extreme toxic outcomes, such as paralysis, blindness or mortality. This is true even for individuals consuming well over 60 g/day of trophic level 4 (TL4) fish from Clear Lake. In Minamata Bay, where such overt toxicity occurred, consumption by affected individuals was estimated to be around 300 g/day (about 9 meals/week). Levels of mercury in fish in Minamata Bay ranged from 10 to 50 ppm (Mahaffey, 1999).

### *USEPA Consumption Rates*

The USEPA recommends default consumption rates for the general population and various subpopulations. These rates were released in October 2000 as part of the revised Methodology for Deriving Water Quality Criteria for Protection of Human Health (USEPA, 2000b). Default consumption rates are derived from data collected nationwide as part of the 1994-96 USDA Continuing Survey of Food Intake by Individuals (CFSII). Default rates are intended by the USEPA to be used when site-specific information is unavailable or inadequate. In the revised Methodology for Deriving Water Quality Criteria, rates are reported separately for consumption of freshwater and marine fish. The USEPA recommends a default fish intake rate of 17.5 g/day to adequately protect the general population consuming freshwater and estuarine fish. This value represents the 90<sup>th</sup> percentile consumption rate for all survey participants, including those who do not eat fish. In selecting the 90<sup>th</sup> percentile, rather than the mean or median, the USEPA intended to recommend a consumption rate that is protective of a majority of the entire population of consumers and non-consumers. The USEPA recommends default fish intake rates of 142.2 g/day for subsistence fishers and 17.5 g/day for recreational fishers, based on consumption of fresh/estuarine fish only (not marine fish).

The USEPA rate for intake of marine fish (12.46 g/day) is not recommended by the USEPA as a default, but is given in order to estimate intake of commercial, mainly marine, fish for people who consume both commercial and locally caught fish. The value of 12.46 g/day is the average consumption of marine fish reported by all respondents in the 1994-95 CFSII. As the 1994-95 CFSII indicates, many consumers eat a combination of locally caught and commercial fish. Total consumption by the 90<sup>th</sup> percentile of survey participants is therefore higher than 17.5 g/day. Commercial and marine fish, as well as sport fish, are sources of mercury.

Various consumption rates have been used by the USEPA in the past for default rates and other purposes. In 1980, the USEPA recommended a consumption rate of 6.5 g/day, which was the “default” rate nationwide and has been adopted by other agencies. This rate was derived from data on non-marine fish and shellfish consumption collected in the early 1970s, for both locally-caught and commercial fish. The 6.5 g/day value was equivalent to the average per-capita consumption rate of all freshwater and estuarine fish and shellfish for the United States population (USEPA, 1980). Based upon food surveys conducted in the 1980s and 1990s, the 6.5 g/day consumption rate was widely considered to be too low. Later rates used by the USEPA for general populations were higher. The USEPA selected 15 g/day as the consumption rate for the Final Great Lakes Water Quality Guidance (USEPA, 1995b). The rate used in the Great Lakes Guidance was derived using West and colleagues’ analysis of the Michigan Statewide Survey and several other studies and intended to be specific to the Great Lakes. For the CTR, the USEPA used a consumption rate of 18.7 g/day for calculation of the mercury criteria<sup>4</sup> (USEPA,

---

<sup>4</sup> In the CTR, a consumption rate of 6.5 g/day was used to calculate criteria for other bioaccumulative constituents (USEPA, 2000a). The use of a higher consumption rate for calculation of the mercury criteria can be found in the Federal Register

1997e). The 18.7 g/day value was based on the average total intake of fish and shellfish from fresh, estuarine, coastal and ocean waters. The revised Methodology for Deriving Human Health Criteria was released after the final CTR.

### *Consumption of Fish from Various Trophic Levels*

Species and size of fish as well as consumption rate affect methylmercury intake. It is difficult to estimate amounts of various species of sport fish that might be consumed from Clear Lake. The principal fish species eaten from Clear Lake, as listed in the Clear Lake consumption advisory and in the Harnly study arranged by trophic level<sup>5</sup> are shown in Table 5. Because diets of white catfish, brown bullhead, and white and black crappie include fish and zooplankton, they are listed as belonging to trophic level 3 (TL3) and TL4.

Table 5. Principal Sport Fish in Clear Lake

Trophic Level of Adult Fish	Species
Trophic level 4	largemouth bass, channel catfish, black crappie and white crappie
Trophic level 3	Sacramento blackfish, hitch, sunfishes, bluegill and black bullhead
Trophic level 3 and 4	white catfish and brown bullhead

The Mercury Report to Congress describes an average, adult high-end consumer as eating only TL4 fish (USEPA, 1997d). In the Final Water Quality Guidance for the Great Lakes, the USEPA represented human consumption of sport fish as being one quarter from TL3 and the remainder from TL4 (USEPA, 1995b). Nationwide food survey data used in calculation of the USEPA methylmercury water quality criterion also show that, on average, individuals consume fish from multiple trophic levels. The USEPA methylmercury water quality criterion assumes that on average, humans eat fish from trophic levels two (21%), three (46%) and four (33%) (USEPA, 2001b).

A rough estimate can be made of the proportions of Clear Lake fish of various trophic levels that are consumed. Angler catch was recorded by Department of Fish and Game during creel surveys conducted in 1988 and 1993-94 (Macedo, 1991; Cannata, 2000). The 1993-94 creel survey also recorded the percentage of fish released. Nearly all fish were kept except for largemouth bass, of which 83% were released. Assuming that all fish kept were consumed, the creel survey data indicated that the approximate proportions of fish consumed from Clear Lake were 70% from TL4 and 30% from TL3. These proportions were used for the TMDL to estimate current exposures to mercury from Clear Lake fish. Clear Lake supports a commercial fishery for

---

notice of the Proposed CTR (USEPA, 1997e). The source of the consumption rates used in the Proposed CTR was not specified.

<sup>5</sup> In this Numeric Target Report, trophic levels are identified as: level 1 – phytoplankton; level 2 – zooplankton; level 3 – organisms that consume zooplankton, benthic invertebrates and phytoplankton; level 4 - organisms that consume trophic level 3 fish. These definitions of trophic levels are also used in the Mercury Report to Congress. Trophic levels used in the USEPA methylmercury water quality criterion are not defined. Trophic level 2 can include fish and invertebrates that are herbivores.



Sacramento blackfish, goldfish and carp, which are exported mainly to markets in the San Francisco Bay area (Bairrington, 2000). The volume of fish removed from Clear Lake through the commercial fishery was not included in the calculation of proportions of TL3 and TL4 fish consumed by sport fishers.

### *Mercury Exposure from Commercial Fish*

Consumption studies indicate that many people who eat sport fish also eat fish purchased commercially. Because methylmercury is present in commercial fish, potential exposure to mercury by ingestion of commercial fish should be considered. Intake of methylmercury from sport or commercial fish depends upon the level in the fish. In the ten most popular types of fish and seafood sold in the United States that comprise 80% of the market, average methylmercury concentrations are less than 0.2 µg/g wet wt. Of the ten most popular types of fish, catfish, clam, pollock, salmon, shrimp and scallops have average levels of methylmercury less than the detection limit of 0.1 µg/g. Average mercury concentrations of other popular types are 0.2 µg/g in canned tuna, 0.13 µg/g in cod, 0.13 µg/g in crab and less than 0.1 to 0.24 µg/g for flatfishes (USFDA, 1995). For calculating human health criteria, USEPA determined that the average mercury concentration in commercial fish weighted by proportions of species consumed is 0.15 µg/g (USEPA, 2001b).

Few consumption studies have reported complete details on the amounts and species of sport and commercial fish consumed. National food surveys have reported total consumption of fish and seafood. The USEPA obtained an estimate of average consumption of commercial (marine) fish by reanalysis of the 1994-95 national food survey data. Regional studies in Santa Monica Bay, San Francisco Bay and Clear Lake reported species and rates of sport fish consumed, but not totals of sport plus commercial fish. A review of the literature found a range from 8 to 24 g/day for consumption rates of commercial fish (Gassel et al., 1997).

In its revised Methylmercury Human Health Criterion, USEPA uses the average consumption rate of marine/commercial species reported in a national consumption survey of 12.46 g/day (approximately one meal every two weeks). Consumption of 12.46 g/day commercial fish results in an average daily intake of 0.027 µg methylmercury/kg/bwt/day. This intake value is used in a later section to estimate the total intake of consumers eating Clear Lake and commercial fish. At Clear Lake, members of the Elem Pomo Tribe reported eating commercial products, including tuna, salmon, crab, snapper and shrimp (Harnly et al., 1997; see Appendix B for complete data tables).

### *Margin of Exposure Analysis for Elem Pomo and Others*

Along with estimating the mercury intake from reported consumption rates, it is useful to compare mercury concentrations in the consumers with known adverse effect levels. Simultaneously with collection of data on fish consumption, CDHS conducted a health assessment of Elem Tribal Members and neighbors of the Sulphur Bank Mercury Mine Site. To evaluate exposure to organic mercury, measurements were made of mercury in blood and hair. Mean mercury concentration in hair was 0.64 µg/g in the Tribal Members, with a range from 0.3 to 2.3 µg/g among total participants. The average blood organic mercury concentration was 15.6 µg/L, with a range from 3.3 to 38.8 µg/L. Blood organic mercury levels did not correlate with the total amount of Clear Lake fish consumed. This lack of correlation likely occurs because mercury concentrations in Clear Lake fish vary and because participants also ate commercial fish. Participants may also have made errors in trying to recall actual consumption over a six-month period. Data tables from the paper are reprinted in Appendix B of this report. These data can be compared with threshold values using a Margin of Exposure (MOE) approach.

The MOE approach provides a method of characterizing risks. The 1997 Presidential/Congressional Commission on Risk Assessment and Risk Management recommended this approach as a common method to be used in protection of environmental and public health (NRC, 2000). The MOE is the ratio of the benchmark dose level to the population exposure level. Because benchmark levels are not adjusted by uncertainty factors, MOEs less than ten indicate that population exposures might be approaching levels of public health concern (NRC, 2000). A MOE analysis of the hair and blood mercury concentrations measured by Harnly and colleagues is shown in Table 6.

As shown in Table 6, mean and maximum levels of mercury in hair and blood of the study participants were above the benchmark dose levels at which adverse effects have occurred. The MOE for average hair mercury level is 19, suggesting that the population is sufficiently protected. In contrast, the MOEs for maximal hair mercury levels and both maximum and mean blood methylmercury levels are less than 10. These data indicate that a minimal 10-fold margin between adverse effect levels and observed levels may not being maintained for parts of this subpopulation of consumers at Clear Lake (Harnly et al., 1997). This group and others who have similar consumption patterns of fish from Clear Lake are potentially at risk for adverse effects of mercury. The MOE analysis indicates that educational efforts should be directed toward high consumers, including the Elem Pomo Tribe and possibly other Native American Tribes, to reduce potential risks.

Table 6. Margin of Exposure Analysis of Bioindicators in Fish Consumers Living near SBMM

Bioindicator	Observed Levels	Benchmark Level	Margin of Exposure
--------------	-----------------	-----------------	--------------------

	in Elem Tribal Members & Non- tribal Neighbors	(b)	(Benchmark ( Observed Level)
Hair mercury			
Mean of Elem Pomo	0.64 µg/g	12 µg/g	19
Mean of neighbors	1.6 µg/g	12 µg/g	7.5
Maximum all participants	2.3 µg/g	12 µg/g	5.2
Blood organic mercury			
mean Elem Pomo(a)	15.6 µg/L	58 µg/L	3.7
maximum	38.8 µg/L	58 µg/L	1.5

(a) Mean is for Elem Pomo Tribal Members only. Mean for non-tribal neighbors was not presented. The maxima are for all participants in the study.

(b) The benchmark level in hair is approximately equivalent to the benchmark dose level upon which the USEPA reference dose is based, which is 58 µg/L in umbilical cord blood. Conversions are from the NRC report (NRC, 2000).

## CONSUMPTION RATE AND NUMERIC TARGET – RECOMMENDATIONS

Selecting a consumption rate involves consideration of the total consumption rate of locally caught fish, species and sizes of fish eaten, and expected consumption rate of commercial fish. To better compare these factors, potential consumption rates are examined in context of the entire fish tissue target. Table 7 shows estimated intakes of methylmercury by for several consumption rates and species consumption patterns. Intakes were calculated using Equations 1 and 2 in Figure 1.

The range of consumption rates under consideration was narrowed to two: the USEPA default rate for the general population and sport fishers and the mean consumption rate of consumers in San Francisco Bay. The USEPA default rate of 17.5 g/day is the best available value that describes consumption by the majority of the general population (90<sup>th</sup> percentile). It is also the default rate for consumption by recreational or sport fishers of locally caught fish. USEPA's rates were determined from a large, nationwide survey. The San Francisco Bay study provides the most comprehensive data from a population of fish consumers in Northern California. The value of 23 g/day is the average consumption of locally caught fish by recent consumers, i.e., those who ate fish four weeks prior to the interview. Presumably the "recent consumer" category includes many of the high-consuming individuals. Although some participants did eat more than 23 g/day, seventy percent of recent consumers in San Francisco Bay ate about 23 g/day or less.

The consumption survey of members of the Elem Pomo Tribe and a few neighbors (Harnly et al., 1997) was not used for the final comparison of consumption rates and targets. It is the only study available that is specific to Clear Lake. It is a very small study, however, with 68 participants. Average consumption rates of Clear Lake fish were influenced by the high consumption rates of several individuals. A Margin of Exposure analysis of mercury in hair and blood did not clearly show that participants were at risk of adverse effects. This study is very important because it shows that a high-consuming population exists at Clear Lake. The study

did not attempt to identify consumption rates for the general population at Clear Lake. Based upon census figures obtained from the Lake County Visitors' Center, participants in the Harnly study represent approximately 0.1 % of the total population of Lake County. For the TMDL, Regional Board staff proposes a total consumption rate that represents a broader proportion of the population of consumers. Regional Board staff highly recommends that additional, more comprehensive consumption data be collected for Clear Lake and/or for inland waters of Northern California.

Two patterns of consumption from various trophic levels are compared in Table 7. Estimated intakes of methylmercury were calculated for the default trophic level distribution and the site-specific data from Clear Lake. Site-specific data should be used in calculation of the Clear Lake TMDL targets, with respect to the types of fish from Clear Lake consumed. The USEPA default values for calculating human health criteria used estimates of proportions of fish consumed from trophic levels 2, 3, and 4 of 3.8, 8, and 5.7 g/day, respectively. This distribution of fish from the trophic levels does not appear to be representative of consumption patterns at Clear Lake. In a 1993-94 creel survey conducted by Department of Fish and Game at Clear Lake, anglers were asked numbers of fish kept and released (Cannata, 2000). Approximate proportions of fish from Clear Lake kept by sport anglers were 70% from trophic level 4 and 30% from trophic level 3. Assuming that all fish kept were consumed, people at Clear Lake eat more trophic level 4 fish than the national average.

Regional Board staff assumed that, in general, consumers of Clear Lake fish also eat commercial fish. Surveys of the Elem Pomo Tribe, San Francisco Bay anglers, and nationwide all support this assumption. The value assumed was that recommended by USEPA to calculate human health criteria, which is that consumers eat approximately two meals per month (12.5 g/day) of commercial fish. In Table 7, estimated intakes of methylmercury are compared with the acceptable daily intake from locally caught fish. The acceptable intake from locally caught fish is obtained by subtracting the assumed daily intake from commercial fish from the reference dose.

Table 7 shows the estimated methylmercury intake by consumers based upon consumption rate, proportions of fish from different trophic levels, existing mercury concentrations in Clear Lake fish and standard consumer body weight. Estimated intakes are compared with the acceptable daily intake of methylmercury from locally caught fish. Consumers eating USEPA's default consumption rate and proportions of trophic have a methylmercury intake that is 10% greater than the acceptable daily intake from local fish. Consumers eating the equivalent of USEPA's default rate (17.5 g/day) and Clear Lake-specific proportions of trophic level 3 and 4 fish receive a methylmercury exposure that is 35% greater than the acceptable daily intake from local fish<sup>6</sup>.

---

<sup>6</sup> Note that consumers of 17.5 g/day do not exceed the USEPA reference dose for total methylmercury intake (0.1 µg/kg-day) by 35%. This calculation assumes that consumers eat approximately two meals per month of commercial fish and accounts for the methylmercury so obtained.

A consumer eating 23 g/day of local fish is exposed to methylmercury in local fish at approximately twice the acceptable amount.

**For the Clear Lake TMDL, Regional Board staff proposes numeric targets in fish consumed by humans of 0.13 mg/kg methylmercury in trophic level 3 fish and 0.30 mg/kg in trophic level 4 fish.** The numeric targets are based upon a total consumption rate of local fish of 17.5 g/day and site-specific proportions of trophic levels 3 and 4 consumed. As shown in Table 7, consumption of 17.5 g/day would require fish mercury levels to be reduced by 35%. A 40% reduction from current levels would bring intake of methylmercury to below the acceptable level. The 40% reduction from current levels is equivalent to targets of 0.13 and 0.30 ppm wet weight in trophic levels 3 and 4 fish, respectively. A sample calculation for the TMDL target for trophic level four is shown in Figure 1.

For development of targets for this and other mercury TMDLs, Regional Board staff intend to follow guidelines provided by USEPA in the 2000 Methodology for Deriving Ambient Water Quality Criteria for Protection of Human Health. Although the USEPA presents default rates, it encourages the use of site-specific information. The USEPA recognizes that the level of fish intake varies by geographical location. According to the Revised Methodology,

“...because the level of fish intake in highly exposed populations varies, EPA suggests a four preference hierarchy for States and authorized Tribes to follow when deriving consumption rates that encourages use of the best local, State or regional data available. The four preference hierarchy is: (1) use of local data; (2) use of data reflecting similar geography/population groups; (3) use of data from national surveys; (4) use of EPA’s default intake rates. ...States and authorized Tribes may use either high-end values (such as the 90<sup>th</sup> or 95<sup>th</sup> percentile values) or average values for an identified population that they plan to protect.”

*Methodology for Deriving Ambient Water Quality Criteria for Protection of Human Health, pp. 4-25 and 4-26 (USEPA, 2000b)*

The use of site-specific information is also encouraged by the USEPA in the USEPA water quality criterion for methylmercury (USEPA, 2001b).

Regional Board staff recognize that use of a USEPA default consumption rate is the fourth option in EPA’s preference hierarchy in setting human health criteria (USEPA, 2000b). More consumption information is needed to better characterize the population at Clear Lake that may eat more than 17.5 g/day of local fish. Regional Board staff recommends that a detailed consumption survey be conducted for Clear Lake or nearby inland waters that would provide additional information. The additional data could be used to adjust the numeric target when the Clear Lake TMDL is amended by the Regional Board into the Basin Plan. Site-specific information was used for the TMDL numeric target with respect to the consumption patterns from various trophic levels.

Note that the above equation does not include a determination as to whether the targets are technically feasible. Prior to amending the numeric targets into the Water Quality Plan for the Central Valley Region (Basin Plan), the Regional Board will need to consider economics and whether the desired water quality condition could reasonably be achieved.

#### *Margin of Safety in the Numeric Target for Humans*

The recommended numeric targets contain several safety factors that are designed to provide protection to people that eat more than 17.5 g/day of fish from Clear Lake. The main safety factor is contained in the reference dose. The reference dose of methylmercury is 10 times higher than the level of methylmercury known to cause adverse effects to humans exposed in utero. In addition, the numeric targets correspond to an estimated intake of methylmercury that is below the safe daily intake from local fish (40% reduction from current levels rather than 35% reduction). Finally, the implementation plan will include outreach to Clear Lake consumers, to encourage consumption of smaller fish and lower trophic level species.

## Figure 1. Sample Calculation of the Proposed Numeric Targets for Humans

Equations and sample calculations are shown for one set of values in Table 7 (USEPA general population consumption rate and fish tissue concentrations from Clear Lake). For further explanation of calculation of the safe intake level of methylmercury from local fish, see also the beginning of the section on human fish tissue targets in this report.

### Equation 1 SAFE INTAKE LEVEL FROM LOCAL FISH

RfD – assumed intake from commercial fish = safe intake of methylmercury from local fish

$$0.1 \mu\text{g/kg bwt-day} - 0.027 \mu\text{g/kg bwt-day} = 0.073 \mu\text{g/kg bwt-day}$$

### Equation 2. INTAKE OF METHYLMERCURY FROM CONSUMPTION OF LOCAL FISH

$$\frac{(\text{CRate}_{\text{TL2}} * \text{Fish}_{\text{TL2}}) + (\text{CRate}_{\text{TL3}} * \text{Fish}_{\text{TL3}}) + (\text{CRate}_{\text{TL4}} * \text{Fish}_{\text{TL4}})}{\text{Body weight}} = \text{Intake of methylmercury from Clear Lake fish}$$

$$\frac{(0 \text{ g/day} * 0.18 \mu\text{g}) + (5.3 \text{ g/day} * 0.22 \mu\text{g/g}) + (12.3 \text{ g/day} * 0.5 \mu\text{g Hg/g fish})}{65 \text{ kg bwt}} = 0.112 \mu\text{g/kg bwt-day}$$

### Equation 3. PERCENT DIFFERENCE BETWEEN SAFE AND ESTIMATED INTAKES

$$\frac{\text{Estimated} - \text{safe}}{\text{Estimated intake}} * 100 = \frac{0.112 \mu\text{g/kg bwt-day} - 0.073 \mu\text{g/kg bwt-day}}{0.112 \mu\text{g/kg bwt-day}} * 100 = 35 \%$$

### Equation 4. CALCULATION OF PROPOSED TARGET

In order to safely consume 17.5 g/day, current fish tissue concentrations must be reduced 35% (or must be 65% of current levels):

$$\text{Current level in TL4} * 0.65 = 0.5 \mu\text{g Hg/g fish} * 0.65 = 0.325 \mu\text{g Hg/g fish}$$

To achieve an intake that is below the acceptable daily intake level for local fish, reduce current levels by 40%. For trophic level 4:

$$(0.60 * 0.5 \mu\text{g Hg/g fish}) = 0.30 \mu\text{g Hg/g fish}$$

Table 7. Estimated Exposures to Humans Eating Clear Lake Fish and Proposed Numeric Targets

EXISTING EXPOSURES FROM CLEAR LAKE FISH										
Total Consumption Rates of Locally Caught Fish, g/day	Consumption rate of TL2 fish, g/day	Consumption rate of TL3 fish, g/day	Consumption rate of TL4 fish, g/day	Average mercury concentration in TL2 fish, ppm wet wt	Average mercury concentration in TL3 fish, ppm wet wt	Average mercury concentration in TL4 fish, ppm wet wt	Average mercury concentration in TL4 fish, ppm wet wt	Estimated methylmercury intake from local fish, µg/kg bwt-day	Acceptable daily intake of methylmercury µg/kg bwt-day (c)	% Reduction needed to meet safe intake levels
	Assume proportions of TL2, TL3 and TL4 fish from national diet survey									
17.5 (a)	3.8	8	5.7	0.18	0.22		0.50	0.081	0.073	10
	Assume proportions of TL2, TL3 and TL4 fish taken from Clear Lake									
17.5 (a)	0	5.3	12.3	0.18	0.22		0.50	0.112	0.073	35
23 (b)	0	6.9	16.1	0.18	0.22		0.50	0.147	0.073	50
Numeric Target: Reduce fish tissue concentrations by 40% to allow for safe intake of 17.5 g/day										
Total Consumption Rates of Locally Caught Fish, g/day		Consumption rate of TL3 fish (30% of total), g/day	Estimated Consumption rate of TL4 fish (70% of total) g/day		TARGET: Average mercury concentration in TL3 fish, ppm wet wt	TARGET: Average mercury concentration in TL4 fish, ppm wet wt	Estimated methylmercury intake from local fish, µg/kg bwt-day	Acceptable daily intake of methylmercury, excluding intake from commercial fish, µg/kg bwt-day		
17.5		5.3	12.3		0.13	0.30	0.067	0.073		

- USEPA default consumption rate for the general population of locally caught fish (90<sup>th</sup> percentile) and for recreational anglers (USEPA 2000b)
- Average consumption rate of locally caught fish by recent consumers in San Francisco Bay (SFEI, 2001).
- Acceptable daily intake from local fish is the reference dose minus estimated daily intake from commercial fish.



### Key Points – Human Body Weights, Portion Size, Consumption Rates and Numeric Targets

- The human adult bodyweight recommended for use in the TMDL is 65 kg, the standard weight of a pregnant adult woman.
- Eight ounces is recommended as the average portion size of fish meal consumed by an adult.
- Consumption rates of fish and other seafood determined in various national and regional studies vary widely. The USEPA default rate for the general population, based on a national food survey, is 17.5 g/day of locally caught fish. A comprehensive study of San Francisco Bay anglers reported a mean consumption rate of 23 g/day for recent consumers.
- One small study of consumers at Clear Lake has been conducted with members of the Elem Pomo Tribe and a few neighbors of the Tribe. Although the overall average consumption rate of Clear Lake fish was 60 g/day, only six (10%) participants ate more than 30 g/day. Species consumed in the greatest amounts were catfish and perch.
- Concentrations of mercury in hair and blood of Elem Tribal Members and non-tribal neighbors were below levels known to cause harm. However, average blood organic mercury levels were above the recommended margin of safety, indicating that study participants are potentially at risk.
- Creel surveys suggest that consumers at Clear Lake typically eat 40% of fish from trophic level 3 (bluegill, sunfishes and hitch) and 60% of fish and 4 (catfish, largemouth bass and crappie).
- Consumers are also exposed to methylmercury in commercial fish. A hypothetical consumer eating one meal per month of commercial tuna would take in 0.02 µg/kg bwt/day of mercury (one fifth of the reference dose).
- **For numeric targets for the TMDL, Regional Board staff proposes 0.13 and 0.30 mg/kg (ppm) methylmercury in trophic levels 3 and 4 fish, respectively.** To obtain these targets, fish tissue concentrations corresponding to safe consumption of 17.5 g/day of local fish were calculated, then lowered by an additional safety factor. Targets are based on site-specific consumption patterns of trophic level 3 and 4 fish. Meeting these targets requires a 40% reduction from current fish tissue levels. Targets assume that consumers eat an additional 12.5 g/day of commercial fish.
- Regional Board staff recommends that a consumption survey be conducted to better define consumption patterns for the general population at Clear Lake. Some members of the Elem Pomo Tribe and non-tribal neighbors reported eating more than 17.5 g/day of fish from Clear Lake.
- Consumers eating more than 17.5 g/day are protected by a margin of safety comprised of the uncertainty factor in the reference dose and by setting the targets below the levels needed to meet acceptable daily intakes of methylmercury (40% reduction from current fish tissue levels instead of 35%).

### Comparison with Existing Fish Tissue Values

Table 8 shows fish tissue guidance or regulatory levels that are already in use by various agencies. The table shows assumptions made in setting each level and the purpose for which it was designed. All tissue levels discussed below are expressed as micrograms of mercury per gram of wet weight tissue (µg/g, equivalent to ppm).

### *USFDA Action Level and Other Screening Levels*

The USFDA issued its action level of 1 ppm to regulate seafood sold commercially in the United States. The USFDA action level was based in part on a nationwide total diet study and levels of mercury in commercial seafood. Screening levels set by the USEPA, OEHHA and the San Francisco Bay RWQCB were designed to be “flags” for evaluating fish tissue data from pilot studies. Screening values are not intended to be levels at which consumption advisories should be issued, but instead are intended to identify fish species and chemicals from a limited data set for which more intensive sampling or health evaluation is recommended (Brodberg and Pollock, 1999; USEPA, 1993a). Waterbodies with fish mercury levels above the screening value would be candidates for further investigation.

### *USEPA Fish Tissue Criterion*

The USEPA recently released an ambient water quality criterion for methylmercury, in the form of a concentration in fish tissue (USEPA, 2001b). The recommended criterion of 0.3 µg/g mercury in fish tissue, wet weight, was established to protect human health. It is the concentration in fish tissue that should not be exceeded based on a total consumption of locally caught fish of 17.5 g/day. The USEPA criterion was calculated slightly differently than the proposed TMDL target, in that it assumes different proportions of fish consumed from trophic levels 2, 3, and 4. Clear Lake creel surveys suggest that consumers eat a higher percentage of fish from trophic level 4 and less fish from trophic level 2 than the national average.

Table 8. Fish Tissue Screening Values and Criterion

Organization/ Site	Mercury in fish tissue ( $\mu\text{g/g}$ wet wt)	Description	Reference
USFDA Action Level	1	Equivalent RfD is $0.47 \mu\text{g/kg}$ bwt/day; assumes consumers eat variety of species; protects consumers of fish bought on commercial market.	USFDA, 1984
USEPA	0.3	Methylmercury water quality criterion to protect human health; based on $17.5 \text{ g/day}$ consumption rate, $70 \text{ kg}$ bwt, USEPA RfD minus intake from commercial fish. (c)	USEPA, 2001
USEPA	0.6	Screening value for developmental toxicity, from Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, 2nd Ed; based on $6.5 \text{ g/day}$ consumption, $65 \text{ kg}$ bwt and $0.06 \mu\text{g/kg}$ bwt/day RfD (b)	USEPA, 1995c
OEHHA	0.3	Screening value used for California Lakes Study; assumes $21 \text{ g/day}$ consumption rate, $70 \text{ kg}$ adult, $0.1 \mu\text{g/kg}$ bwt/day RfD. (a)	Brodberg & Pollock, 1999
San Francisco Estuary Institute (SFEI)	0.3	Screening value used for SFEI's most recent survey of Delta fish; same as used by OEHHA for the California Lakes Study. (a)	Davis et al., 2000
SFEI	0.23	Screening value used in the San Francisco Estuary Regional Monitoring Program; based on $30 \text{ g/day}$ consumption, $70 \text{ kg}$ adult and $0.1 \mu\text{g/kg}$ bwt/day. (d)	SFEI, 1999
San Francisco Bay Regional Water Quality Control Board	0.14	Screening value previously used by SFBRWQCB, from USEPA Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, 1st Ed.; assumes $30 \text{ g/day}$ consumption, $70 \text{ kg}$ bwt, $0.06 \mu\text{g/kg}$ bwt/day RfD.	SFBRWQCB, 1995; USEPA, 1993a
Mercury Study Report to Congress	0.36	Corresponds to USEPA RfD; assumes $65 \text{ kg}$ adult and $18 \text{ g/day}$ consumption rate. (c)	USEPA, 1997d

- (a) The  $21 \text{ g/day}$  consumption rate used by OEHHA and SFEI is the median consumption rate ( $50^{\text{th}}$  percentile) for fish consumers reported in the Santa Monica Bay Seafood Consumption Study (Gassel et al., 1997).
- (b) The acceptable intake value of  $0.06 \mu\text{g/kg}$  bwt/day was calculated by the USEPA. It was calculated by dividing the USEPA's mercury RfD (at the time,  $0.3 \mu\text{g/kg}$  bwt/day) by an uncertainty factor of five to protect against developmental toxicity. Prior to 1995, the USEPA's RfD was based upon a critical endpoint of neurotoxicity in adults. Children were postulated to be more sensitive (hence, use of the uncertainty factor), but studies that led to the later refinement of the RfD to protect children had not been completed.
- (c) Consumption rates of  $17.5$  and  $18 \text{ g/day}$ , and are based on similar analyses of data from the USDA 1994-95 Continuing Survey of Food Intake by Individuals.
- (d) The  $30 \text{ g/day}$  consumption rate is a 1990 USEPA estimate of the average consumption of fish from marine, estuarine and fresh waters by the  $50^{\text{th}}$  percentile of recreational fishers, derived from USDA national survey data (USEPA, 1990).

## POTENTIAL WILDLIFE HEALTH TARGETS

Fish-eating birds and mammals are potentially at risk for impairments caused by consumption of mercury-contaminated fish. Mercury studies conducted in the laboratory and field are used to evaluate fish tissue targets that would protect health of wildlife at Clear Lake and to compare those with fish tissue levels recommended to protect humans. Wildlife studies have been reviewed in a report prepared for the Sacramento River Watershed Program on the status of information needed for a numeric target (SRWP, 2000a).

### Mammals

Authors of the Mercury Study Report to Congress (MRC) (USEPA, 1997a, b, c, and d) and the Great Lakes Water Quality Initiative Final Rule (GLWQI) (USEPA, 1995b) selected one set of feeding studies in mink as the basis of water quality criteria recommended in those documents to protect fish-eating mammals. The single-generation investigations conducted by Wobeser and colleagues evaluated endpoints of survival, growth rates, motor control and histologic assessment of neuronal damage following a range of doses (Wobeser et al., 1976a; Wobeser et al., 1976b). No behavioral or reproductive endpoints were evaluated.

The USEPA authored the GLWQI and, several years later, the MRC. Risk assessment methods in the MRC were based upon those in the GLWQI, and expanded to consider potential effects on species in addition to those of concern in the Great Lakes region. The GLWQI effort yielded a final water quality criterion for total mercury in water for protection of piscivorous wildlife. The MRC criteria were calculated using additional information on exposures to methylmercury and dose levels for a wider range of sublethal effects (USEPA, 1997c).

The Sacramento River Watershed Program Candidate Targets Report describes in detail the derivation of the mammalian criteria in the MRC and the GLWQI (SRWP, 1999). The MRC identified 0.33 mg mercury/kg (ppm) diet as the no-observable adverse effect level (NOAEL) in mink. For the Great Lakes Criteria, the USEPA identified 1.1 mg/kg mercury in the diet as the NOAEL. The combination of different NOAELs and uncertainty factors selected by authors of the MRC and the GLWQI, resulted in final acceptable daily intake levels that were extremely close: 0.018 mg Hg/kg bwt/day in the MRC and 0.016 mg Hg/kg bwt/ day in the GLWQI.

Exposure methods and subsequent effects for studies by Wobeser and others in mink are shown in Table 9. Data from one study completed since the MRC measured reproductive success in mink (Dansereau et al., 1999). Dansereau and colleagues found that a diet containing 0.5 µg/g mercury caused a statistically significant decrease in the number of mated females that actually gave birth. This effect was not seen at the 0.1 µg/g dose level. These results indicate that a NOAEL for reproductive success of mink could be less than the 0.3 µg/g NOAEL for neurologic impairment in adult mink. Uncertainty factors were incorporated into derivation of the acceptable daily intake levels in the MRC and GLWQI, in part to account for lack of information

about effects on the next generation. Without a rigorous analysis of the study methodology and reproduction data by Dansereau and colleagues and a comparison with the Wobeser studies, it would be difficult to incorporate the reproduction information into calculation of a revised acceptable daily intake level.

Table 9. Mercury Effects in Mink

Level of Mercury in the Diet	Exposure Type	Effect	Comment (a)	Reference
0.33 (0.44 ppm as 75% of diet)	Subchronic exposure to adults	No clinical or pathological effect.	0.055 mg/kg/d NOAEL for MRC, added UF of 3 for subchronic to chronic	Wobeser et al., 1976a
1 ppm	2 mo.	Death of females.		Kirk, 1971 in: Dansereau et al., 1999
0.5 ppm	3 mo.	No deaths.		
1 ppm	6 mo.	Neurologic lesions, death.	Author concludes 1.0 ppm is LOAEL for adult survival	Wren et al., 1987
0.9 ppm	75 – 100 d	Death of 30/50 females		Dansereau et al., 1999
0.56 ppm	704 d	No deaths		
1.1 ppm	93 d	Neurologic lesions. (Authors expected mink deaths had exposure been longer.)	LOAEL MRC, GLWQI used this as NOAEL with uncertainty factor of 10	Wobeser et al., 1976b
0.5 ppm	430 d	Statistically significant decrease in number of mated females that gave birth (no effect on litter size, kit growth rate through day 35 or on overall kit mortality).		Dansereau et al., 1999
0.1 ppm	430 d	Number of mated females giving birth equivalent to untreated females as reported in literature.	Data suggest NOAEL of 0.1 ppm for gestational success	Dansereau et al., 1999
0.22 ppm	7 mo. (212 d)	Statistically significant decrease in maternal bwt, male kit weight, and litter size.		Halbrook et al., 1997
0.15 ppm	7 mo. (212 d)	No significant effects on maternal bwt, male kit weight, or litter size.		Halbrook et al., 1997

(a) Abbreviations: LOAEL = lowest observed adverse effect level. NOAEL = no observable adverse effect level. MRC = Mercury Study Report to Congress, 1997. GLWQI = Great Lakes Water Quality Initiative, 1995.

## Avian Species

Acceptable daily intake levels for avian species were determined in a manner similar to that used for mink. Both the MRC and GLWQI based their avian RfD on the lowest-observable adverse effect level (LOAEL) determined in a three-generation study of mallard ducks by Heinz and colleagues (Heinz, 1974; Heinz, 1976a; Heinz, 1976b; Heinz, 1979). MRC and GLWQI authors selected the same LOAEL for reproductive and behavioral effects of 0.5 µg/g methylmercury in the diet. Authors of the two reports applied different consumption rates and uncertainty factors,

resulting in slightly different RfDs. The MRC reported an RfD of 0.021 mercury/kg bwt/day and the GLWQI reported an RfD of 0.032 mg/kg bwt/day. Derivation of the avian reference doses is explained more fully in the Sacramento River Watershed Program's report on candidate targets (SRWP, 1999).

A number of field studies of fish-eating birds have been conducted that provide some information about levels of mercury in fish associated with adverse effects. Fish with mercury concentrations in the range of 0.3 to 0.4 ppm wet weight were associated with reduced egg-laying and decreased territorial fidelity by the common loon breeding on mercury-contaminated lakes in northeastern Ontario (Barr, 1986). In a report prepared for the USFWS, Eisler proposed a minimum criterion level of 5.0 ppm, as measured in feathers, for protection of adult birds from toxic effects of mercury. Adverse effects in various species occur in a range from 5 to 40 ppm dry weight in feathers (Eisler, 1987 in: Wolfe et al., 1998). In a separate review, Scheuhammer concluded that birds with feather mercury concentrations above 20 ppm are at risk for toxic effects of mercury (Scheuhammer, 1991). The author estimated that the normal background of mercury in feathers of raptorial birds (including bald eagle and osprey) is 1-5 ppm (Scheuhammer, 1991).

The human reference dose is significantly lower than the avian and mammalian wildlife reference doses, in part, because they are based on different endpoints of toxicity. Studies used to derive the human health reference dose have focused on impairments to fine motor skills, audio-visual function and mental performance. In contrast, studies upon which reference doses for wildlife are based primarily report adverse effects on survival, gross motor skills and reproductive outcomes (Heinz, 1976a; Heinz, 1979; Wobeser et al., 1976a; Wobeser et al., 1976b).

## **Mercury in Wildlife at Clear Lake**

### *Western Grebes*

Mercury levels and nesting success of western grebes at Clear Lake have been studied (Elbert, 1996; Elbert and Anderson, 1998). Nests were surveyed monthly in summers 1992 through 1994. For all three years, productivity (recorded as young/adult ratio) at Clear Lake was well below productivity level recorded as normal for grebes at other western lakes (see Table 10). Concentrations of total mercury in breast muscle, brain and kidney in adult birds from Clear Lake were twice as high as in birds from Tule and Eagle Lakes (statistically significant,  $p < 0.05$ ). Elbert and her colleagues concluded that grebes are reproducing poorly at Clear Lake, but that cause(s) of the decrease are unclear. The authors noted that mercury likely impacts grebe reproduction at Clear Lake. Other factors, such as disturbance from boat traffic, may also impact the western grebe populations at Clear Lake. Eagle Lake has less boat traffic in

nesting areas and Tule Lake has no boat traffic. Mercury levels in the brains of Clear Lake western grebes are below levels expected to result in adverse effects in wild birds.

Table 10. Nesting Success of Western Grebes at Clear Lake and Other Western Lakes (Source: Elbert & Anderson, 1998)

Site	Productivity (# young ÷ # adults)	Years
Clear Lake, CA	0.001 – 0.16	1992 – 1994
Tule Lake & Eagle Lake, CA	0.16 – 0.74	1992 – 1994
Normal productivity, recorded at other western lakes	0.25 – 0.5	1970s (Eagle Lake, CA) 1980s (Bear River Migratory Bird Refuge, UT)

In 1984, the CDFG collected western grebes and American coots from Clear Lake and analyzed them for mercury content (CVRWQCB, 1985). The CDFG reported average concentrations of 6.4 ppm in livers of western grebe, with a range of 3.7 to 9.8 ppm. Livers of grebes collected by Elbert and Anderson (1998) contained an average of 2.7 ppm mercury. A liver concentration of 5 ppm mercury, wet weight, has been associated with adverse neurologic and other significant effects in water birds (Wolfe et al., 1998; Zillioux et al., 1993). Mercury levels in coots were lower (0.02 – 0.06 ppm), which is to be expected for an herbivorous species.

Additional data could be collected to clarify the effect of mercury on grebes at Clear Lake. In the studies by Elbert and colleagues, reproductive success was assessed by measures of productivity (ratio of number of young to number of adults in colony) and hatching success (ratio of number of eggs hatched to number of eggs laid). Eggs may not hatch or be laid due to contamination, predation, abandonment, disturbance, infertility or other factors. A measure of hatching success does not separate likely effects of contamination from these other factors. An alternative measure of reproductive success is hatchability, which is the ratio of number of eggs hatched to the number of eggs incubated to term (Schwarzbach, 2000) (see also Appendix C, Response to Comments). Eggs preyed upon or abandoned would not be counted in the hatchability ratio. This data gap is particularly relevant to Clear Lake, as western grebes are a key indicator species (Schwarzbach, 2000). Western grebes regularly nest at Clear Lake. During periods of nesting and raising young, the grebes feed exclusively in the lake.

#### *Additional Bird Species*

Feathers were collected from nesting, fish-eating birds at Clear Lake in the early 1990s (Suchanek et al., 1997). Adult osprey showed the highest mercury values with an average of 20 µg/g dry weight. Adult western grebes and great blue herons had average mercury levels in feathers of 9.74 and 7.4 µg/g, respectively. Mercury concentrations averaged 5.25 µg/g in juvenile osprey and 6.5 µg/g in juvenile double-crested cormorant. Osprey at Clear Lake had elevated concentrations of mercury when compared to control sites near St. Joe and Coeur d'Alene, Idaho and in Baja, California. A concentration of mercury in feathers of 20 ppm, is

equivalent to the toxic risk level for birds identified by Scheuhammer (Scheuhammer, 1991). A thorough baseline study of mercury in feathers at Clear Lake has not been undertaken.

In a separate study involving birds at Clear Lake, Wolfe and Norman (1998) found no significant difference between growth rates of great blue heron nestlings raised at Clear Lake and young heron in colonies in relatively pristine sites in Washington and Nova Scotia. The number of young per active great blue heron nest at Clear Lake was comparable to reproductive success rates in heron colonies from sites not contaminated with mercury. Concentrations of mercury in great blue heron and double crested cormorant nestlings were below tissue mercury concentrations associated with toxicity in young birds.

Field observations have shown that 0.3 ppm mercury in fish is the dietary threshold for reproductive impairment in common loon (Barr, 1986, in: Wolfe et al., 1998). The impact of this level of mercury depends upon sizes of fish eaten by loons and other birds and levels of mercury in potential prey fish in Clear Lake. Levels of mercury in Clear Lake fish suggest loons could reach the reproductive threshold. The overall, average mercury concentration in Clear Lake fish likely eaten by loons is less than 0.3 ppm. Mercury concentrations in catfish and largemouth bass of appropriate prey size for loons are above 0.3 ppm (0.33 to 0.37 ppm for 140 to 250 mm long fish). Loons feed at Clear Lake, but do not nest there in large numbers. Western grebes are similar to loons taxonomically, and do nest at Clear Lake in large numbers. Most piscivorous birds at Clear Lake, with the exception of raptors, however, would be expected to consume prey smaller than that eaten by loons (Schwarzbach, 2000) (see Appendix C, Response to Comments).

Safe fish tissue levels of 0.09 ppm have been calculated for common mergansers and western grebes by Dr. Steven Schwarzbach of the USFWS (Schwarzbach, 2000). The fish tissue target values were provided for the Great Lakes Water Quality Initiative (USEPA, 1995a) and the San Francisco Bay Protection and Toxic Cleanup Program. The target was based upon a reference dose from the Heinz studies with mallards and species-specific consumption rates and body weights for grebes and mergansers.

### *Mammalian Wildlife*

Little information exists about mercury in mammalian wildlife at Clear Lake. Mercury has been measured in tissues of some mammals caught near the shores of Clear Lake (Wolfe and Norman, 1998). Levels of mercury in the brain and fur of raccoons were below no observable effect levels reported in the literature for wild mammals. The number of raccoons examined was not reported. Seven of eight mink examined also had mercury levels below those associated with adverse effects. The 7.1 ppm mercury measured in the brain of one adult mink is just above the threshold level for adverse effects in mink (5 ppm mercury in brain) (Wolfe and Norman, 1998). Although all but one mink captured by Wolfe and Norman contained mercury levels below literature values for toxicity, the number of mink examined was small. Laboratory data showing decreased reproductive success at dietary levels around 0.1 – 0.2 ppm mercury (Dansereau et al.,



1999; Halbrook et al., 1997) suggest that mink could be experiencing decreased reproductive success from consuming trophic level 3 fish from Clear Lake. There are no field data available on effects of mercury in mammalian wildlife at Clear Lake. The potential for mink and/or otter at Clear Lake to suffer reproductive or other adverse effects from consumption of Clear Lake fish should not be disregarded.

A preliminary assessment of hazards to wildlife from mercury and arsenic at Clear Lake was prepared for the 1994 Remedial Investigation Report for Sulphur Bank Mercury Mine (Elbert, 1993). Mercury concentrations in tissues of Clear Lake wildlife were compared with tissue concentrations and effects in published literature. Elbert concluded that mercury concentrations in prey fish from Clear Lake are unlikely to cause lethality of top-trophic level wildlife species. Mercury concentrations in prey fish could be high enough to cause reduced hatching success and/or behavioral abnormalities and reduced survival of young. Mercury concentrations in adult wildlife could be enough to cause behavioral abnormalities, such as reduced nest attendance, which can result in reduced reproductive output (Elbert, 1993).

### Potential Numeric Targets for Wildlife

Acceptable fish tissue levels of mercury for wildlife species can be calculated in the same manner as for humans by incorporating daily intake levels, body weights and consumption rates. The equation to be used is the same:

$$\frac{\text{Reference dose} * \text{Body weight}}{\text{Consumption rate}} = \text{Acceptable level in prey fish}$$

As in the human health section, we have rearranged the equation, in order to compare estimated daily intakes of methylmercury from existing fish tissue concentrations with the reference dose.

For an organism eating fish from TL3 and TL4, the calculation is:

$$\frac{(\text{CRate}_{\text{TL3}} * \text{Fish}_{\text{TL3}}) + (\text{CRate}_{\text{TL4}} * \text{Fish}_{\text{TL4}})}{\text{Body weight}} = \text{Estimated intake of methylmercury from Clear Lake fish}$$

Where:

CRate<sub>TL3</sub> = consumption rate of trophic level 3 fish

Fish<sub>TL3</sub> = mercury concentration in trophic level 3 fish

A sample calculation for river otter is:

$$\frac{(0.15 \mu\text{g Hg/g})(976 \text{ g fish/day}) + (0.45 \mu\text{g Hg/g})(244 \text{ g fish/day})}{7.4 \text{ kg bwt}} = 35 \mu\text{g Hg/kg bwt/day}$$

Species-specific factors of consumption rate and body weight can be used with reference doses to estimate amounts of mercury consumed. In the MRC, daily exposure rates for wildlife species were estimated as the product of methylmercury levels in fish eaten and the daily amount of fish eaten. A similar estimation can be made using average mercury concentrations in fish from Clear Lake. Estimated mercury exposures were calculated using actual fish tissue concentration data from Clear Lake (CVRWQCB, 1985; Suchanek et al., 1997; Suchanek et al., 1993). See Appendix A for Clear Lake fish tissue data.

### *Reference Doses*

Following the risk assessment methods used in the GLWQI and MRC, an acceptable daily intake level determined for mink is assumed to be appropriate for other mammalian wildlife species. Using the mink feeding studies by Wobeser, MRC authors determined a reference dose for mammalian wildlife of 0.018 mg/kg bwt/day. Likewise, an acceptable daily intake level determined for mallard ducks is used for all birds. Mallard reproduction studies by Heinz et al. (Heinz, 1974; Heinz, 1976a; Heinz, 1976b; Heinz, 1979) were used to determine an avian reference dose of 0.021 mg/kg bwt/day (USEPA, 1997c).

### *Body weights and Consumption Rates*

Wildlife species most likely at risk for mercury toxicity are primarily or exclusively piscivorous. Table 11 lists species potentially at risk along with their body weights and consumption rates. Authors of the MRC selected two mammals and four bird species of concern in habitat across the country. All of these species occur regularly at Clear Lake. The following species of concern for Clear Lake have been added to the basic list from the MRC: western grebe, common merganser, great blue heron and double crested cormorant. Otter, raptors and loon eat larger fish, on average, than the other wildlife mentioned. Kingfishers likely eat fish in the smallest size range.

Exposure parameters needed to estimate daily mercury exposures to wildlife are given in Table 10. Most exposure parameters of body weight and consumption rates were obtained from the USEPA Exposure Factors Handbook (1993b), the Mercury Report to Congress (USEPA, 1997b) and from US Fish and Wildlife Service (Haas, 2001). Bodyweights and prey types for great blue heron juveniles were determined by a field study at Clear Lake (Wolfe and Norman, 1998). All other exposure parameters are averages obtained from published literature of various field and laboratory studies. In using these values to calculate targets, it is assumed that average literature values reflect consumption and growth patterns of animals at Clear Lake. Data on individuals at Clear Lake are not available to test this assumption.

### *Existing Mercury Concentrations in Clear Lake Fish*

Average mercury concentrations in trophic levels 2, 3 and 4 fish in Clear Lake fish assumed to be consumed by wildlife are shown in Table 12. In general, wildlife species are assumed to eat a smaller size range of fish than do humans. Existing fish tissue concentrations were determined from Clear Lake fish tissue data (CVRWQCB, 1985; Suchanek et al., 1993; Suchanek et al., 1997). The concentration of mercury in trophic level 4 fish ( $0.45 \mu\text{g/g}$ ) used in the wildlife calculations was slightly smaller than that used for humans. Based on the exposure parameters in Table 10, the TL4 concentration used for wildlife is the average mercury concentration in TL4 fish less than 450 mm in length. Wildlife species are assumed to eat trophic level 2 fish, such as inland silversides and juvenile fish, which are not favored by humans. In order to incorporate this difference in wildlife consumption, the average concentration of mercury in TL2 and TL3 fish ( $0.15 \mu\text{g/g}$ ) was used for the wildlife calculations. A complete data set on concentrations of mercury in small and mid-sized fish at Clear Lake is lacking. Average concentrations of mercury in fish 40-200 mm length could be higher or lower than these estimates, depending upon abundance and ease of capture of various species and sizes. A concentration of  $0.12 \mu\text{g/g}$  is the average concentration in inland silversides and juvenile largemouth bass smaller than 100 mm (Suchanek et al., 1997).

Table 11. Exposure Parameters for Fish-eating Wildlife

Fish-eating Species	Approximate Size of Fish Consumed (6) (mm)	Estimated Fish Ingestion Rate Trophic Level 2 – 3 (g fish/day, wet wt)	Estimated Fish Ingestion Rate Trophic Level 4 (g fish/day, wet wt)
River otter (1, 5)	300 - 450	976	244
Mink (1)	50 - 200	160	0
Bald eagle (1, 5)	75 - 450	370	90
Osprey (1)	75 - 450	300	0
Loon (1)	200 - 400	800	0
Common merganser (4, 6)	< 350	302	0
Double-crested cormorant (2, 6)	100 - 250	310	0
Western grebe (4, 6)	< 350	374	0
Great blue heron juveniles (3)	< 100	245	0
Kingfisher (1)	40 -140	75	0

Exposure parameters are from the USEPA Exposure Factors Handbook (USEPA, 1993b). Fish size and ingestion estimates also provided by US Fish and Wildlife Service (Haas, 2001; Schwarzbach, 2001). Values from the reports listed below vary slightly from the Handbook due to: rounding of numbers; selection of values for males, females or both; or slight differences in conversion of dry weight diet measurements to wet weight. For comparison, an average two-pound channel catfish from Clear Lake is 320 mm (just over 12 inches) long.

- 1) Species and exposure parameters in the Mercury Study Report to Congress, Vol. 7 (USEPA, 1997d).
- 2) Additional species evaluated for the Great Lakes Water Quality Initiative, also nests at Clear Lake (USEPA, 1995a).
- 3) Prey species based on field observations at Clear Lake Wolfe and Norman, 1998.
- 4) Exposure parameters provided by Schwarzbach, 2001. Mergansers are known to take fish up to 350 mm length, but prey size is limited by fish girth.
- 5) River otter and bald eagle consume fish from TL3 and TL4. The ratio of TL3/TL4 fish eaten by adults is estimated to be 80/20 for otters and 74/18 for bald eagles (8% of bald eagle's diet is not aquatic) (USEPA, 1993b). Bald eagles are scavengers, and thus could eat fish from a wide size range.
- 6) For species eating a wide variety of sizes in the 50 – 350 size range, the total consumption was split between TL2-3 less than 100 mm and TL3 fish greater than 100 mm

### *Estimated Daily Intakes of Methylmercury and Numeric Targets for Wildlife*

Estimated daily intakes of methylmercury by wildlife species are shown in Table 12. Under existing conditions at Clear Lake, all wildlife species of concern except for bald eagles are believed to exceed their acceptable daily intake of methylmercury. River otter and kingfishers exceed the safe daily intakes by 50% or more. Mink, osprey, loon, common merganser, western grebe and great blue herons are estimated to exceed the safe daily limits by 15 – 40%. Double crested cormorant are exposed to mercury at just above the acceptable level.

There are several sources of uncertainty in the estimated daily intakes for wildlife shown in Table 12. A significant source of uncertainty is whether the standard avian and mammalian reference doses are appropriately applied to all of the species of concern. Particular species may exhibit greater or lesser sensitivity to toxic effects of methylmercury than is assumed. The

CALFED Bay Delta Program has funded US Fish and Wildlife Service to assess effects of mercury on birds using field observations and laboratory exposures. Target species for this research include cormorants and herons found at Clear Lake. The risks to birds at Clear Lake should be reassessed when data from the CALFED study are available.

Other sources of uncertainty in the exposure estimates are the quantity and concentration of mercury in prey fish eaten at Clear Lake. Uncertainty in levels of mercury in prey fish could be reduced by additional data on mercury concentrations in Clear Lake fish of the sizes consumed by wildlife. More data exists for sizes and species of fish normally caught by humans.

Uncertainty in consumption rates of various sizes and trophic levels of fish could be reduced by in-depth feeding studies of wildlife at Clear Lake. Biological variation limits the degree to which uncertainty in wildlife consumption can be eliminated. Total daily consumption and the range of fish sizes consumed by a species are derived from published data and probably very similar for Clear Lake and other waterbodies. The average size of fish may vary, however, from published values. For example, sizes and species of fish consumed by otter in Clear Lake may vary due to variations in yearly and seasonal abundance of prey, prey preference or other factors.

Because of uncertainties in reference doses, consumption patterns of Clear Lake fish, and whether wildlife at Clear Lake are being adversely impacted by mercury, Regional Board staff is not recommending separate fish tissue targets to protect wildlife. Wildlife at Clear Lake may be at risk, but data showing a clear link between mercury concentrations and adverse effects is lacking. Instead of setting targets, the effects on wildlife intakes of methylmercury of achieving the human health targets were examined. Reaching the human health targets requires a 40% reduction from current levels of fish tissue mercury. Estimated intakes of mercury by wildlife species in the event of a 40% reduction from current, average mercury concentrations in fish consumed by wildlife are shown in Table 13.

A reduction of fish tissue concentrations by 40% corresponds to mercury concentrations of 0.09 µg/g in trophic level 2-3 fish and 0.27 µg/g in trophic level 4 fish less than 450 mm in length. The final targets are in line with fish tissue targets recommended for western grebe and common merganser of 0.09 µg/g (Schwarzbach, 2000). These fish tissue concentrations are estimated to be protective of all species except for river otter and kingfisher. The Regional Board is concerned that all species be protected from adverse effects of mercury in Clear Lake. River otters and kingfishers are present at Clear Lake throughout the year and likely obtain most of their food from the lake. Methylmercury intake by kingfishers, however, may be overestimated. Kingfishers likely eat the smallest fish available, which have less methylmercury than the average concentration in trophic level 2-3 fish used to calculate the intake. To achieve safe intake levels for river otters, an additional 10% reduction from current fish tissue levels would be required. River otter may also eat more trophic level 2 fish from Clear Lake than is indicated by literature values shown in Table 11.

Regional Board staff does not recommend lowering the fish tissue targets to achieve the estimated safe intakes for river otter and kingfisher. The estimates of safe daily intake are based on literature values of consumption and on reference doses derived for species other than these. Consumption patterns and adverse effects of methylmercury on these species at Clear Lake have not been examined. Regional Board staff recommends that studies be conducted to assess the effects of mercury on wildlife. Studies should be conducted to assess effects on populations in the field and/or in the laboratory to refine reference doses. In particular, field and laboratory studies of bird exposures to be completed by USFWS should be examined. Additional information could alter species of concern at Clear Lake, estimated intakes or reference doses. Regional Board staff should evaluate new information relative to wildlife risks prior to amending the Clear Lake TMDL targets into the Basin Plan.

#### *Margin of Safety for Wildlife*

The recommended numeric targets contain a margin of safety for wildlife that eat fish from Clear Lake. The avian and mammalian reference doses each contain an uncertainty factor of three. These uncertainty factors lower the reference doses below levels of mercury known to cause adverse effects to mallards and mink, respectively. Although the uncertainty factors were not applied to account for species differences, they do provide some measure of protection to wildlife that may be more sensitive to effects of mercury.

Table 12. Estimated Methylmercury Intake by Wildlife at Clear Lake and Comparison with Acceptable Intakes

	Estimated consumption, g/day wet wt (a)		Body weight	Average mercury concentration in Clear Lake fish, µg/g wet wt (b)		Estimated daily intake	Reference dose (c)	ratio of RfD to exposure	% Reduction needed to meet RfD
	TL 2-3	TL 4		TL 2-3	TL 4				
river otter	976	244	7.4	0.15	0.45	35	18	0.5	50
bald eagle	370	90	4.6	0.15	0.45	21	21	1.0	0
mink	160	0	0.8	0.15	0.45	30	18	0.6	40
osprey	300	0	1.5	0.15	0.45	30	21	0.7	15
loon	800	0	4	0.15	0.45	30	21	0.7	15
merganser	302	0	1.23	0.15	0.45	37	21	0.6	30
cormorant	310	0	1.7	0.15	0.45	27	21	0.8	5
western grebe	354	0	1.48	0.15	0.45	35	21	0.6	25
Great blue heron juvenile	245	0	1.0	0.15	0.45	37	21	0.6	30
kingfisher	75	0	0.15	0.15	0.45	75	21	0.3	65

a) Estimated consumption is based on size and amounts of fish consumed. See Table 10.

b) Average mercury concentrations in Clear Lake fish from CVRWQCB, 1985; Stratton et al., 1987; and Suchanek et al., 1997, Concentration in TL4 is for fish up to 450 mm length. Concentration in TL 2-3 is the average concentration in TL3 fish plus inland silversides and juvenile largemouth bass.

c) USEPA 1997c

Table 13. Effect on Wildlife Intakes of Methylmercury of Forty Percent Reduction in Current Fish Tissue Levels									
	Estimated consumption, g/day wet wt		Body weight, kg	Average mercury concentration in fish, µg/g wet wt (a)		Estimated daily intake	Reference dose	ratio of RfD to exposure	% Reduction from current levels needed to meet safe intake
	TL 2-3	TL 4		TL 2-3	TL 4	µg/kg bwt day	µg/kg bwt day		
river otter	976	244	7.4	0.09	0.27	21	18	0.9	10
bald eagle	370	90	4.6	0.09	0.27	13	21	1.7	0
mink	160	0	0.8	0.09	0.27	18	18	1.0	0
osprey	300	0	1.5	0.09	0.27	18	21	1.2	0
loon	800	0	4	0.09	0.27	18	21	1.2	0
merganser	302	0	1.23	0.09	0.27	22	21	1.0	0
cormorant	310	0	1.7	0.09	0.27	16	21	1.3	0
western grebe	344	0	1.48	0.09	0.27	21	21	1.0	0
Great blue heron juveniles	245	0	1.0	0.09	0.27	22	21	1.0	0
kingfisher	75	0	0.15	0.09	0.27	45	21	0.5	25
(a) Fish tissue concentrations are a 40% reduction from existing average fish tissue concentrations of mercury. This parallels the 40% reduction needed to meet the human health targets.									



### Key Points – Potential Wildlife Health Targets

- Studies are lacking for wildlife that relate quantified mercury exposure to sublethal or reproductive endpoints. Field studies of effects of mercury are especially lacking. In cases in which adverse effects of mercury on wildlife are hypothesized, such as impaired nesting success of western grebes at Clear Lake, follow-up studies have not been conducted to separate effects of mercury from confounding environmental factors.
- Estimated daily intakes of methylmercury can be calculated for wildlife species of concern, using standard references for birds and mammals and species-specific consumption information. Most parameters are derived from published literature and are assumed to be appropriate for Clear Lake.
- Wildlife consuming fish from Clear Lake are likely to exceed acceptable daily intake levels of mercury, based on consumption rates from the literature and known Clear Lake fish tissue mercury levels. River otter, mink, and kingfishers exceed the safe daily intakes by 40% or more
- Poor nesting success of western grebes at Clear Lake may be due, in part, to mercury. Reproduction of double crested cormorant, great blue heron and osprey at Clear Lake do not appear to be impaired by mercury.
- Acceptable daily intake levels (reference doses) for mammalian and avian wildlife have been developed using limited data. These reference doses should be refined or validated using multi-generational studies that address effects on reproduction and neurological development.
- Because of uncertainties in reference doses, consumption patterns of Clear Lake fish, and whether wildlife at Clear Lake are being adversely impacted by mercury, Regional Board staff is not recommending separate fish tissue targets to protect wildlife. Instead of setting targets, the effects on wildlife intakes of methylmercury of achieving the human health targets were examined.
- If mercury concentrations in fish eaten by wildlife are reduced by 40%, all species except for river otter and kingfisher are expected to be protected. River otter is estimated to exceed the safe daily intake by 10% and kingfishers by 25% of current levels. Estimated safe fish tissue concentrations required by western grebes and mergansers would be achieved by a 40% reduction from current levels.
- Methylmercury intake by kingfishers is possibly overestimated. Kingfishers likely eat the smallest fish available, which have less methylmercury than the average concentration in trophic level 2-3 fish used to calculate the intake.
- Regional Board staff should evaluate new information relative to wildlife risks prior to amending the Clear Lake TMDL targets into the Basin Plan.

### REFERENCES

- Abu-Saba, K.E. and Tang, L.W., 2000. Watershed Management of Mercury in the San Francisco Bay Estuary: A Total Maximum Daily Load Report to USEPA, San Francisco Bay Regional Water Quality Control Board, Staff report, Oakland, CA.
- ATSDR, 1999. Toxicological Profile for Mercury. Fact sheet on MRLs available at: <http://www.atsdr.cdc.gov/mrls.html>, U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta.
- Bakir, F., Damluji, S.F. and Amin-Zaki, L., 1973. Methylmercury poisoning in Iraq. *Science*, 180: 230-41.
- Bairrington, P.K., 2000. Clear Lake Fishery Management Plan. California Department of Fish and Game, Wildlife and Inland Fisheries Division, Fisheries Program Branch. Yountville, CA January.
- Brodberg, R.K. and Pollock, G.A., 1999. Prevalence of Selected Target Chemical Contaminants in Sport Fish From Two California Lakes: Public Health Designed Screening Study. Final Project Report,

Office of Environmental Health Hazard Assessment, Pesticide and Environmental Toxicology Section, Sacramento, CA.

- Burger, J. and Gochfeld, M., 1997. Risk, mercury levels, and birds: relating adverse laboratory effects to field biomonitoring. *Environmental Research*, 75: 160-172.
- Cannata, S., 2000. Personal communications from Steve Cannata, Fisheries Biologist, Department of Fish and Game, Lakeport Field Office to Janis Cooke, Environmental Specialist, Central Valley Regional Water Quality Control Board. October 19 and 30, 2000.
- Crump, K.S., Kjellstrom, T., Shipp, A.M., Silvers, A. and Stewart, A., 1998. Influence of prenatal mercury exposure upon scholastic and psychological test performance: benchmark analysis of a New Zealand cohort. *Risk Analysis*, 18(6): 701-713.
- CVRWQCB, 1985. Summary of Mercury Data Collection at Clear Lake. Staff report, Central Valley Regional Water Quality Control Board, Sacramento, CA.
- CVRWQCB, 1998. The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board - Central Valley Region, Fourth Edition. Central Valley Regional Water Quality Control Board, Sacramento, CA.
- Dansereau, M., Lariviere, N., Du Tremblay, D. and Belanger, D., 1999. Reproductive performance of two generations of female semidomesticated mink fed diets containing organic mercury contaminated freshwater fish. *Archives of Environmental Contamination and Toxicology*, 36: 221-226.
- Davidson, P.W., G. J. Myers, C. Cox, C. Axtell, C. Shamlaye, J. Sloane-Reeves, E. Cernichiari, L. Needham, A. Choi, Y. Wang, M. Berlin, and T. W. Clarkson. 1998. Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment. *Journal of the American Medical Association*, 280(8): 701-707.
- Davis, J.A., May, M.D., Ichikawa, G. and Crane, D., 2000. Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, CA.
- Elbert, R.A., 1993. Ecological Assessment of the Sulphur Bank Mercury Mine Superfund Site Wildlife Study Report: Heavy Metal Hazards to Wildlife of Clear Lake, Lake County, CA. Department of Wildlife, Fish and Conservation Biology, UC Davis. In: Remedial Investigation/Feasibility Study, Sulphur Bank Mercury Mine Superfund Site, Clearlake Oaks, CA. US EPA Region 9. August 1994 Report.
- Elbert, R.A., 1996. Reproductive performance and mercury exposure of birds at Clear Lake, CA, Masters Thesis, University of California, Davis, Davis, CA.
- Elbert, R.A. and Anderson, D.W., 1998. Mercury levels, reproduction and hematology in western grebes from three California Lakes, USA. *Environmental Toxicology and Chemistry*, 17(2): 210-213.
- Gassel, M., Brodberg, R.K., Pollock, G.A. and Fan, A.M., 1997. Chemicals in Fish Report No. 1: Consumption of Fish and Shellfish in California and the United States. Final Draft Report. Available at: <http://www.oehha.org/fish/pdf/fishrpt.pdf>, Pesticide and Environmental Toxicology Section. Office of Environmental Health Hazard Assessment. California Environmental Protection Agency, Berkeley, CA.
- Grandjean, P., P. Weihe, R. F. White, F. Debes, S. Araki, K. Yokoyama, K. Murata, N. Sorensen, R. Dahl, and P. J. Jorgensen. 1997. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. *Neurotoxicology and Teratology*, 19: 17-28.

- Grandjean, P., White, R.F., Nielsen, A., Cleary, D. and de Oliveira Santos, E.C., 1999. Methylmercury neurotoxicity in Amazonian children downstream from gold mining. *Environmental Health Perspectives*, 107(7): 587-591.
- Haas, J., 2001. Personal communication from Jim Haas, US Fish and Wildlife Service, Sacramento Office, regarding typical sizes of fish consumed by wildlife. To Janis Cooke, Environmental Specialist, Central Valley Regional Water Quality Control Board. 3 January 2001.
- Halbrook, R.S., Lewis, L.A., Aulerich, R.I. and Bursian, S.J., 1997. Mercury accumulation in mink fed fish collected from streams on the Oak Ridge Reservation. *Archives of Environmental Contamination and Toxicology*, 33: 312-316.
- Harnly, M., S. Seidel, P. Rojas, R. Fornes, P. Flessel, D. Smith, R. Kreutzer, and L. Goldman. 1997. Biological monitoring for mercury within a community with soil and fish contamination. *Environmental Health Perspectives*, 105(4): 424-429.
- Heinz, G.H., 1974. Effects of low dietary levels of methylmercury on mallard reproduction. *Bulletin of Environmental Contamination and Toxicology*, 114: 386-392.
- Heinz, G.H., 1976a. Methylmercury: Second-generation reproductive and behavioral effects on mallard ducks. *Journal of Wildlife Management*, 40(4): 710-715.
- Heinz, G.H., 1976b. Methylmercury: Second-year feeding effects on mallard reproduction and feeding behavior. *Journal of Wildlife Management*, 40(1): 82-90.
- Heinz, G.H., 1979. Methylmercury: Reproductive and behavioral effects on three generations of mallard ducks. *Journal of Wildlife Management*, 43(2): 394-401.
- Huber, K., 1997. Wisconsin Mercury Sourcebook. Wisconsin Dept. Natural Resources, Bureau of Watershed Management, Madison.
- Macedo, R.A., 1991. Creel Survey at Clear Lake, California, March - June, 1988. Department of Fish and Game, Region 3. Inland Fisheries Administrative Report No. 91-3.
- Mahaffey, K.R., 1999. Methylmercury: A new look at the risks. *Public Health Reports*, 114: 397-413.
- Marsh, D.O., Clarkson, T. W., Cox, C., Myers, G. J., Amin-Zaki, L., and Al-Tikriti, S. 1987. Fetal methylmercury poisoning: Relationship between concentration in single strands of maternal hair and child effects. *Archives of Neurology*, 44(10): 1017-1022.
- McCalady, J.L., Mack, E.E., Nelson, D.C. and Scow, K.M., 2000. Sediment microbial community structure and mercury methylation in mercury-polluted Clear Lake, California. *Applied and Environmental Microbiology*, 66(4): 1479-1488.
- Moyle, P.B., 1976. *Inland Fishes of California*. University of California Press, Berkeley.
- Nichols, J., Bradbury, S. and Swartout, J., 1999. Derivation of wildlife values for mercury. *Journal of Toxicology and Environmental Health Part B* 2: 325-355.
- NRC, 2000. Toxicological Effects of Methylmercury. Available at <http://www.nap.edu/books/0309071402/html>, National Research Council, Committee on the Toxicological Effects of Mercury. Published by National Academy Press, Washington, DC.
- OEHHA, 1999. California Sport Fish Consumption Advisories 1999. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.
- OEHHA, 2000. Evaluation of Potential Health Effects of Eating Fish from Black Butte Reservoir (Glenn and Tehama Counties): Guidelines for Sport Fish Consumption. Draft Report, Pesticide and

Environmental Toxicology Section, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.

- OSTP, 1998. Report of the Workshop on Scientific Issues Relevant to Assessment of Health Effects from Exposure to Methylmercury. Report available at: [http://ntp-server.niehs.nih.gov/main\\_pages/PUBS/MethMercWkshpRpt.html#execsumm](http://ntp-server.niehs.nih.gov/main_pages/PUBS/MethMercWkshpRpt.html#execsumm). Committee on Environmental and Natural Resources, Office of Science and Technology Policy (OSTP), The White House, Raleigh, NC.
- Popkin, B.M., Haines, P.S. and Reidy, K.C., 1989. Food consumption trends of U.S. women - patterns and determinants between 1977 and 1985. *American Journal of Clinical Nutrition*, 49: 1307-1319.
- Scheuhammer, A.M., 1991. Effects of acidification on the availability of toxic metals and calcium to wild birds and mammals. *Environmental Pollution* 71: 329-375.
- Schwarzbach, S., 2000. Personal communication from Dr. Steven Schwarzbach, Chief of the Environmental Contaminants Division, Sacramento Office, U.S. Fish and Wildlife Service to Janis Cooke, Environmental Specialist, Central Valley Regional Water Quality Control Board. 26 September 2000. Data on grebe and mergansers also used in the Bay Protection and Toxic Cleanup Program's Draft Regional Toxic Hot Spot Cleanup Plan, Central Valley Region, March 1999.
- SFBRWQCB, 1995. Contaminant Levels in Fish Tissue from San Francisco Bay. Final Report. San Francisco Bay Regional Water Quality Control Board, staff report, Oakland.
- SFEI, 1999. Contaminant Concentrations in Fish from San Francisco Bay, 1997, San Francisco Estuary Institute (SFEI). Technical report prepared for the San Francisco Estuary Regional Monitoring Program for Trace Substances, Richmond, CA.
- SFEI, 2001. San Francisco Bay Seafood Consumption Study, Final Report. San Francisco Estuary Institute, Richmond, CA.
- Sigel, A. and Sigel, H. (Editors), 1997. Mercury and Its Effects on Environment and Biology. *Metal Ions in Biological Systems*, 34. Marcel Dekker, New York, 604 pp.
- Speirs, R.S. and Speirs, M., 1998. Environmental Mercury - An Immunotoxic Perspective. In: L.B. Webber and T.H. Suchanek (Editors), *Second Annual Clear Lake Science and Management Symposium*, Lakeport, CA, pp. 86-94.
- SRWP, 1999. Sacramento River Watershed Program: Determination of Candidate Targets for the Mercury Strategic Planning Effort - Draft Report. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).
- SRWP, 2000a. Sacramento River Watershed Program: Identification and Assessment of Candidate Target for the Mercury Strategic Planning Effort - Status Report. Prepared by Larry Walker Associates for the Sacramento River Watershed Program.
- SRWP, 2000b. Mercury Sources in the Sacramento River Watershed - Preliminary Report. Prepared by Larry Walker Associates for the Sacramento River Watershed Program.
- Stratton, J.W., F., S.D., Fan, A.M. and Book, S.A., 1987. Methylmercury in Northern Coastal Mountain Lakes: Guidelines for Sport Fish Consumption for Clear Lake (Lake County), Lake Berryessa (Napa County) and Lake Herman (Solano County). Hazard Evaluation Section and the Epidemiological Studies and Surveillance Section, Office of Environmental Health Hazard Assessment, California Department of Health Services, Berkeley.
- Suchanek, T.H., 2000. Personal communication from Dr. Tom Suchanek, Professor, Department of Wildlife, Fish and Conservation Biology, University of California Davis and Director of the UC Davis Clear Lake Environmental Research Center, regarding exceedances of 50 ng/L mercury water

- quality criterion. To Janis B. Cooke, Environmental Specialist, Central Valley Regional Water Quality Control Board, 22 December 2000.
- Suchanek, T.H., McHatton, S. C., Nelson, D. C., Slotton, D. G., Ayers, S. M., Webber, L. B., Swisher, B. J., Bern, A. L., Flanders, J. R. and Luke, B. K. 2000. Mercury in Clear Lake Fishes: Spatial and Temporal Trends. Northern California Society of Environmental Toxicology And Chemistry Conference, 10 April, Davis, CA. Abstract.
- Suchanek, T.H., Richerson, P.J., Mullen, L. H., Brister, L. L., Becker, J. C., Maxson, A. E., Slotton, D.G. 1997. The Role of the Sulphur Bank Mercury Mine Site in the Dynamics of Mercury Transport and Bioaccumulation within the Clear Lake Aquatic Ecosystem. Interim Final Report. Prepared for the USEPA Region 9 Superfund Program.
- Suchanek, T.H., Richerson, P.J., Woodward, L.A., Slotton, D.G., Holts, L.J., Woodmansee, C.E. 1993. Preliminary Lake Study Report - A Survey and Evaluation of Mercury in: sediment, water, plankton, periphyton, benthic invertebrates and fishes within the aquatic ecosystem of Clear Lake, California. University of California, Davis report prepared for EPA Region 9, Ecological Assessment: Sulphur Bank Mercury Mine Superfund Site, Clear Lake, Davis, CA.
- Toffleson, L. and Cordle, F., 1986. Methylmercury in fish: a review of residual levels, fish consumption and regulatory action in the United States. *Environmental Health Perspectives*, 68: 203-8.
- Tsubaki, T.K. and Irukayama, K. (Editors), 1977. *Minamata Disease*. Elsevier, Amsterdam.
- USEPA, 1980. U.S. Environmental Protection Agency, Federal Register, 45:79347-79357 (Nov. 28). Appendix C - Guidelines and Methodology Used in the Preparation of Health Effect Assessment Chapters of the Consent Decree Water Criteria Documents.
- USEPA, 1990. Exposure Factors Handbook. EPA-600/8-89/043, U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC.
- USEPA, 1993a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1 Fish Sampling and Analysis. First Edition. EPA 823-R-93-002, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology.
- USEPA, 1993b. Wildlife Exposure Factors Handbook. EPA/600/R-93/187a, U.S. Environmental Protection Agency Office of Science and Technology, Washington, DC.
- USEPA, 1995a. Great Lakes Water Quality Initiative Technical Support Document for Wildlife Criteria. EPA/820/B-95/009, U.S. Environmental Protection Agency. Office of Water, Washington. DC.
- USEPA, 1995b. U.S. Environmental Protection Agency, Federal Register, Vol. 60, No. 56 (Thurs. 23 March, 1995). Final Water Quality Guidance for the Great Lakes System.
- USEPA, 1995c. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1 Fish Sampling and Analysis. Second Edition. EPA-823-R-95-007, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington DC.
- USEPA, 1997a. Mercury Study Report to Congress Vol. 3: Fate and Transport of Mercury in the Environment, Office of Air Quality Planning & Standards and Office of Research & Development, U.S. Environmental Protection Agency.
- USEPA, 1997b. Mercury Study Report to Congress Vol. 4: An Assessment of Exposure to Mercury in the United States. EPA-452/R-97-006, Office of Air Quality Planning & Standards and Office of Research & Development, U.S. Environmental Protection Agency.

- USEPA, 1997c. Mercury Study Report to Congress Vol. 6: An Ecological Assessment for Anthropogenic Mercury Emissions in the United States, Office of Air Quality Planning & Standards and Office of Research & Development, U.S. Environmental Protection Agency.
- USEPA, 1997d. Mercury Study Report to Congress Vol. 7: Characterization of Human Health and Wildlife Risks from Mercury Exposure in the United States, Office of Air Quality Planning & Standards and Office of Research & Development, U.S. Environmental Protection Agency.
- USEPA, 1997e. U.S. Environmental Protection Agency, Federal Register, Vol. 62, No. 150 (Tues. 5 August, 1997). Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Proposed Rule.
- USEPA, 2000a. U.S. Environmental Protection Agency, Federal Register, Vol. 65, No. 97 (Thurs. 18 May, 2000). Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule.
- USEPA, 2000b. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). EPA-822-B-00-004, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology.
- USEPA, 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. Final Document. EPA-823-F-01-001, U.S. Environmental Protection Agency, Office of Science and Technology, Office of Water, Washington, DC.
- USFDA, 1984. Shellfish Sanitation Interpretation: Action Levels for Chemical and Poisonous Substances. U.S. Food and Drug Administration (USFDA).
- USFDA, 1995. Mercury in Fish: Cause for Concern?, U.S. Food and Drug Administration. Original article appeared in September 1994 issue of FDA Consumer. Article with revisions available at: <http://www.fda.gov/opacom/catalog/mercury.html>.
- WHO, 1990. Environmental Health Criteria 101: Methylmercury. World Health Organization (WHO), Geneva.
- Wiener, J.G. and Spry, D.J., 1996. Toxicological significance of mercury in freshwater fish. In: W.N. Beyer, G.H. Heinz and A.W. Redmon-Norwood (Editors), Environmental Contamination in Wildlife: Interpreting Tissue Concentrations. CRC Press, Inc., Boca Raton, FL, pp. 297-339.
- Wobeser, G., Nielsen, N.O. and Schiefer, B., 1976a. Mercury and mink I: The use of mercury contaminated fish as food for ranch mink. Canadian Journal of Comparative Medicine, 40: 30-33.
- Wobeser, G., Nielsen, N.O. and Schiefer, B., 1976b. Mercury and mink II: Experimental methyl mercury intoxication. Canadian Journal of Comparative Medicine, 40: 34-45.
- Wolfe, M.F. and Norman, D., 1998. Effects of waterborne mercury on terrestrial wildlife at Clear Lake: Evaluation and testing of a predictive model. Environmental Toxicology and Chemistry, 17(2): 214-227.
- Wolfe, M.F., Schwarzbach, S. and Sulaiman, R.A., 1998. Effects of mercury on wildlife: A comprehensive review. Environmental Toxicology and Chemistry, 17(2): 146-60.
- Wren, C.D., Hunter, D.B., Leatherland, J.F. and Stokes, P.M., 1987. The effects of polychlorinated biphenyls and methylmercury, singly and in combination, on mink. I: Uptake and toxic responses. Archives of Environmental Contamination and Toxicology, 16: 441-447.
- Zillioux, E.J., Porcella, D.B. and Benoit, J.M., 1993. Mercury cycling and effects in freshwater wetland ecosystems. Environmental Toxicology and Chemistry, 12(12): 2245-2264.

## APPENDIX A

## MERCURY IN CLEAR LAKE FISH

Levels of mercury in various fish species are reported below as the average and standard deviation of total mercury per wet weight of tissue. Raw data collected by Department of Fish and Game, Department of Health Services and Central Valley Regional Water Quality Control Board (CVRWQCB, 1995) and the UC Davis-Clear Lake Environmental Research Center (Suchanek et al., 1993; Suchanek et al., 1997) were tabulated and combined for statistical analyses. Although the data were collected over a time period of 25 years, there are no obvious trends in mercury concentrations between the older and more recently collected data.

Abbreviations for fish species used in the following graphics are:

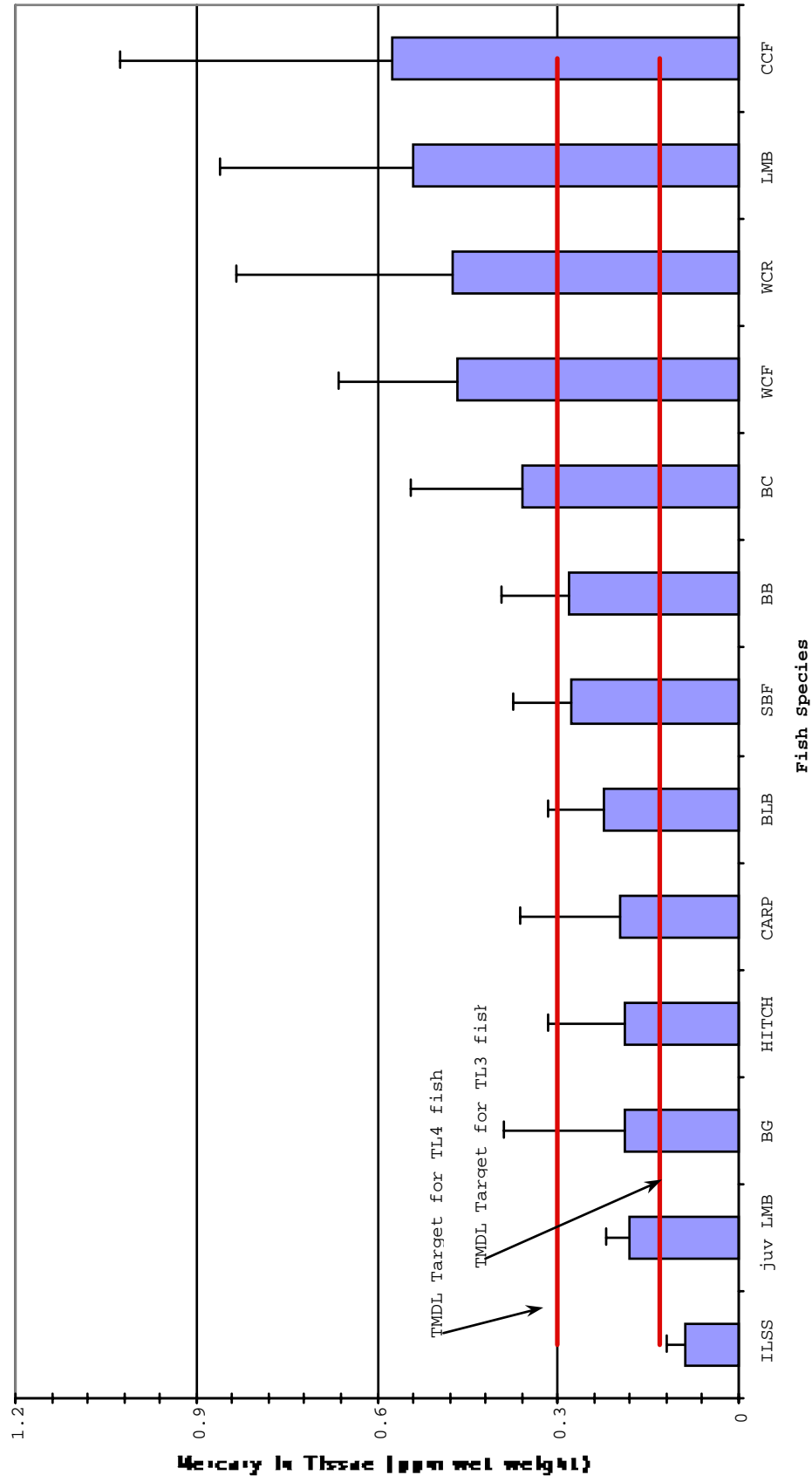
ILSS	inland silverside
juv LMB	juvenile largemouth bass
BG	blue gill
BLB	black bullhead
SBF	Sacramento blackfish
BB	brown bullhead
BC	black crappie
WCF	white catfish
WCR	white crappie
LMB	largemouth bass
CCF	channel catfish

For inland silversides and juvenile largemouth bass, data reported is for size classes of 65 - 80 mm and 100-200 mm, respectively. These are size classes likely eaten by small, piscivorous birds.

Table A.1. Forklengths of Fish Caught by Anglers in March through June, 1988 at Clear Lake (Source: Macedo, 1991.)

Species	Length Range (mm)
Black crappie	115 – 310
Bluegill	115 – 200
Brown bullhead	300 – 430
Channel catfish	390 – 780
Green sunfish	118 – 163
Largemouth bass	190 – 590
White catfish	245 – 455
White crappie	180 – 330

# Average Levels of Mercury in Fish at Clear Lake





# Concentrations of Mercury in Clear Lake Fish

Sources: CVRWQCB, 1985; Suchanek et al., 1993; Suchanek et al., 1997

Table A-2. Mercury Tissue Concentrations in Clear Lake Fish, by Species (ppm wet weight):

Fish Species	ILSS	juv LMB	bluegill	hitch	carp	BLB	SBF	BB	black crappie
Mean	0.09	0.18	0.19	0.19	0.20	0.22	0.28	0.28	0.36
Standard Deviation	0.03	0.04	0.20	0.13	0.17	0.09	0.10	0.11	0.19
Fish Species	white crappie	channel catfish	white catfish	LMB					
Mean	0.48	0.48	0.51	0.54					
Standard Deviation	0.36	0.37	0.18	0.32					

Table A-3. Mercury concentrations in fish categories most commonly consumed by humans (ppm wet weight):

Fish Species	Average Concentration of Trophic Level 3 (includes bluegill, hitch, carp, Sacramento blackfish and black bullhead; catfish less than 250 mm forklenght and largemouth bass 150-175 mm) (a)	Average concentration of TL4 fish. (Includes black crappie and white crappie longer than 140 mm forklenght; brown bullhead, white catfish and channel catfish longer than 250 mm; and largemouth bass longer than 175 mm)
Mean	0.22	0.50

(a). (Small bass and catfish categorized as TL3 fish because of probable prey consumed by these sizes of fish)

Table A-4. White and Channel Catfish mercury concentrations by length range (ppm wet weight)

	catfish length (mm)								
	126-250	251-300	301-350	351-400	401-450	451-500	501-550	600-655	701-750
Mean	0.29	0.40	0.39	0.41	0.30	0.39	0.51	1.26	0.97
Standard Deviation	0.18	0.19	0.20	0.15	0.12	0.21	0.15	0.22	0.52

Table A-5. Largemouth Bass Mercury Concentrations by Length Range (ppm wet weight)

	largemouth bass length (mm)								
	144-200	201-250	251-300	301-350	351-400	401-450	451-515		
Mean	0.32	0.41	0.46	0.47	0.56	0.73	1.14		
St Dev	0.15	0.18	0.20	0.34	0.26	0.40	0.41		
Std. Dev.	0.15	0.18	0.20	0.34	0.26	0.40	0.41		

## APPENDIX B

### ASSESSMENT OF HUMAN EXPOSURE TO MERCURY AT CLEAR LAKE

Following is summary data from the California Department of Health Services study of mercury exposure to members of the Elem Pomo Tribe and some non-Native American neighbors of the Sulphur Bank Mercury Mine [Harnly, 1997 #15]. The study was conducted in November, 1992 by Harnly and colleagues. Sixty-three Tribal Members (46% of the resident tribal population) and four residents of neighboring, non-tribal homes participated in biological monitoring. The first centimeter of hair closest to the scalp was analyzed. For sport and commercial fish consumption, respondents were asked what type they had consumed over the past six months, the estimated average number of times per week they ate the fish, and the average amount (in pounds) they ate at each meal. Children under ten years of age were interviewed with their parents.

This survey was conducted after the fish consumption advisory was in effect for Clear Lake. Fish consumption rates, by members of the Elem Pomo Tribe and other Native American Tribes in the Clear Lake watershed, were likely higher prior to the advisory.

Table A-4 shows average consumption rates as reported in the published paper. The text of the paper, however, states that 90% of those interviewed consumed at a rate equal to or less than 30 g/day. It is clear from this statement that the average consumption rates were heavily influenced by the amounts of fish eaten by a few, high-consuming individuals.

Table B-1. Biological Mercury Levels Among Clear Lake Health Study Participants

Participants	N	Mean	Minimum	Maximum	Standard Deviation
Blood inorganic mercury ( $\mu\text{g/L}$ )					
Tribal Members	44	2.9	0.7	4.7	1.0
Others	4	2.7	1.7	3.4	0.8
Blood organic mercury ( $\mu\text{g/L}$ )					
Tribal Members	44	15.6	3.3	38.8	6.6
Others	4	8.8	2.5	12.2	6.9
Hair mercury ( $\mu\text{g/g}$ )					
Tribal Members	63	0.64	0.3	1.8	0.43
Others	4	1.6	0.3	2.3	0.88

From [Harnly, 1997 #15]. For samples less than the detection limit (0.3 – 0.6  $\mu\text{g/g}$ ), the value was taken as 0.3  $\mu\text{g/g}$ .

Table B-2. Fish consumption rates among consumers in mercury health effects survey at Clear Lake

	Number of individuals reporting consumption (a)	Average consumption among consumers (g/day)
<b>Clear Lake fish</b>		
Total of Clear Lake fish	23	60
Catfish	19	53
Hitch	4	12
Perch	4	74
Bass	2	5
Carp	1	1
<b>Commercial fish</b>		
Total of commercial fish	32	24
Tuna	15	9
Salmon	12	9
Crab	8	9
Snapper	5	10
Shrimp	5	6

(a). Includes study participants who reported eating fish within the 6 month period prior to the survey. Study participants were members of the Elem Pomo Tribe and several non-tribal neighbors. (Harnly et al., 1997)

## APPENDIX C

### **Response Summary to Comments Received on the Preliminary Draft of the Clear Lake Mercury TMDL Numeric Target Report**

The following are Regional Board staff responses to comments received on the Preliminary Draft version of the Numeric Target Report, which was released in August 2000. Comments have been responded to individually here. Where indicated, corresponding changes have been made to the text of the report. Regional Board staff appreciates the effort and thoughts of all who submitted comments. Comments are presented in bold; Regional Board responses are in plain type.

Stan Smucker, USEPA Region 9

**I briefly reviewed the "Clear Lake TMDL for Mercury Numeric Target Report Preliminary Draft" (dated August 2000) from the California Regional Water Quality Control Board, Central Valley Region. I concur with their analysis. It is appropriate and well thought out. Consumption of fish with mercury concentrations at or less than 0.1 ppm (wet weight) pose *de minimus* human health risks.**

**If you have further questions, call me.**

(No response necessary)

---

Bob Brodberg, Chief of the Fish and Water Quality Evaluation Unit, Office of Environmental Health Hazard Assessment (OEHHA). Transcription of phone conversation regarding the Mercury Numeric Target Report and on mercury risk assessment in general. September 21, 2000.

**Regarding selection of a reference dose, neither OEHHA nor any other agency in CalEPA has officially adopted any reference dose. OEHHA will be analyzing data from recent and ongoing mercury epidemiology studies, in order to develop a reference dose. In the meantime, OEHHA is currently using the USEPA reference dose for mercury (0.1 micrograms/kg body weight per day). The existing EPA reference dose value is likely the most conservative that would be developed. We don't expect to adopt a reference dose that is any lower.**

**There are other options for a reference dose that is protective of unborn children, including the Minimum Risk Level established by Agency for Toxic Substances and Disease Registry (0.3 micrograms/kg body weight per day) and the reference doses developed by ICF Consulting for fish consumers in Lavaca Bay (Clewett et al., 2000). With the National Research Council now supporting the USEPA reference dose level, it would be difficult to adopt a different reference dose until new study results are available.**

**The Regional Board could select its own reference dose for the TMDLs. The Regional Board could take the EPA, ATSDR or other benchmark dose level and apply its own uncertainty factor. If an agency within the California Environmental Protection Agency officially establishes use of a particular mercury reference dose, it might be harder for the Regional Board to justify use of a different one.**

Until OEHHA has completed its evaluation of the literature and has adopted a reference dose, Regional Board staff believes that the USEPA reference dose is the most appropriate value to use for the mercury numeric target. If OEHHA or USEPA were to select a different reference dose, Regional Board staff would reevaluate the target and adjust it as necessary.

Options for the benchmark dose level for methylmercury and uncertainty factors, and the data behind these values have been scrutinized carefully by the Committee of the National Research Council and again by USEPA in setting the new reference dose for methylmercury in December 2000. The uncertainty factor of 10 that was used in the 1995 USEPA reference dose was upheld in review by both scientific groups. Until new data is analyzed, Regional Board believes that the benchmark and uncertainty factors used in calculation of the Dec., 2000 USEPA reference dose are most appropriate for protecting fish-consuming populations.

**It appears that the Regional Board has the most leeway in selecting consumption value(s). In part, this becomes a policy decision.**

Yes, this is in part a policy decision. The definition of “fishable” for Clear Lake will need to be determined by the Regional Board with the approval of the State Water Resources Control Board and U.S. EPA. Public comment on the draft target report was specifically sought regarding fishing practices at Clear Lake and implications of the numeric target. We will continue to seek public response to this issue.

**When communicating the target, it is easier for the public to understand terminology such as meals per week, than the level in fish tissue. You might consider converting fish tissue levels to goals of being able to eat a certain amount of various species per time period. This also works as a target. For example, is the goal to be able to eat one meal per month of catfish, or one meal per week?**

The target expressed as a mercury level in fish tissue is preferred for the TMDL, because monitoring data in fish tissue can be compared directly to the target to evaluate progress. We agree, that from a public communication perspective, consumption rates in meals per week is easier to understand. The target assumes consumption of about two meals per week. We have clarified this in the report and will keep this issue in mind when interpreting the target to the public.

- 1. There is only a limited discussion describing the process of mercury TMDL development. It would be helpful to list the other TMDL documents that will be developed and the expected completion dates. It would be also be helpful to describe how the target report fits in with other reports that have already been developed, future reports, and a description of how the target will be achieved. We would also recommend that an estimate to reach the fish tissue target be provided (i.e 50-100 years).**

We have added much more information about the plan for TMDL development, time schedule, reports that will be prepared and opportunities for public comment. Please see the revised Introduction to the report. We have also added a discussion of using interim milestone targets in addition to the final TMDL target (see end of the Human Health target section). Because the source quantification and linkage analysis elements of the TMDL for Clear Lake have not yet been completed, we do not know how the target will be achieved or how long it will take.

- 2. This report indicates that there is poor correlation between water column data and fish tissue concentrations. Is it anticipated that water column data will not be used to measure effectiveness of Waste Load Allocations and Load Allocations that will be developed in the future?**

The Regional Board has contracted with UC Davis Clear Lake Environmental Research Center to provide additional water column data and site-specific bioaccumulation factors, which should clarify the relationships between mercury concentrations in water and biota. This data will be available in Spring 2001. Regarding use of water column measurements to evaluate effectiveness of load reduction activities, please see response to your Comment 17. We anticipate that the fish tissue target will be converted to a water column number for the linkage analysis element of the TMDL. A converted water column number could be used as a measure of effectiveness.

#### Executive Summary

- 3. Page 1: It is stated that feasibility and economic considerations will be addressed as a program of implementation is developed. Under the current USEPA interpretation of federal requirements, the program of implementation does not have to be developed or included in the TMDL prior to approval by USEPA. A number of TMDLs in California have been adopted by USEPA upon completion of preliminary work by the State of California (Regional Board or SWRCB). Postponement of these considerations to the program of implementation stage may result in the establishment of a target which has not been evaluated for economic or technical feasibility. We encourage the inclusion of these evaluations in the TMDL documentation prior to June 2001.**

Regional Board staff has committed to providing a TMDL Report to U.S. EPA by June 2001. This commitment is associated with the Federal grant funds that the State receives from U.S. EPA. Regional Board staff views the TMDL Report as one component in the overall process to develop and implement a water quality management strategy for mercury contamination in Clear Lake. Prior to the implementation of such a strategy, Regional Board staff will develop an implementation plan and a Basin Plan Amendment. The Basin Plan Amendment must be approved by the Regional Board, State Water Resources Control Board, Office of Administrative Law, and the Environmental Protection Agency. In the case of the Clear Lake mercury water quality management strategy, it is anticipated that the U.S. EPA's Superfund program will be developing a great deal of information regarding technical feasibility and cost. That information will be considered by Regional Board staff as part of the process to adopt a Basin Plan Amendment. To the extent that the analysis of feasibility and cost information are not included in the TMDL Report, Regional Board staff will include appropriate qualifications of the results and conclusions of the TMDL Report.

- 4. We request that the target report describe how and when final targets will be adopted. The process and timing for modifying the target (a) as a result of work completed under the TMDL implementation step or (b) as part of a Basin Plan amendment should be described in greater detail. On one hand, the report states that the Regional Board must set targets which are "safe", "protective", "fully protective", etc. On the other hand, the report states that the final target "may be modified based on consideration of economics, technical feasibility as well as...the scientific merit of the methodologies...and assumptions..." outlined in the target report. What process will be used to reach decisions which balance these considerations? When will that process be undertaken? What flexibility will the Regional Board have to adopt a target that is higher than the target value proposed in this report?**

Language has been added in the target report to describe in more detail the process for adoption of the target.

- 5. Page 2: The stated schedule for adoption of a Basin Plan amendment to support this TMDL is 2002 or 2003. Has the Regional Board received any indication from USEPA regarding their intent to usurp the Regional Board's efforts and adopt the Clear Lake TMDL as a federal TMDL prior to completion of the Basin Plan amendment process?**

Staff from the U.S. EPA has indicated to Regional Board and State Board staff that there is an expectation of progress towards incorporating TMDLs and accompanying implementation plans into the Basin Plans. U.S. EPA staff has previously indicated that the Regional Board staff's proposed schedule for incorporation of the TMDL for Clear Lake into the Basin Plan is adequate.

6. **Page 2:** It is stated that “high levels” of mercury exist in fish in Clear Lake, and that “elevated levels” of mercury have been measured in lake sediment, water, birds and other organisms. These statements should be accompanied by (a) tables showing the values in question and the comparable values from other locations and (b) comments differentiating between elevated levels and levels associated with adverse effects.

There is more complete information on levels of mercury in water, sediment and biota in the body of the report. The main text also includes comparisons with adverse effect levels in the sections on Selection of Target (human health values) and Clear Lake Wildlife. Fish tissue data is now available in Appendix A.

7. **Page 2:** The mercury fish tissue data collected since 1970 should be summarized in an appendix to this report. Data should include species, size, number and location, if available.

Fish tissue data has been added in Appendix A.

8. **Page 3:** It is noted in the report that the California Toxics Rule standard of 50 nanograms per liter (ng/l) for total mercury in the water column applies to Clear Lake and may be used as a secondary target for the TMDL. Since the TMDL must ensure compliance with adopted standards, it seems imperative that the TMDL use the 50 ng/l value as a target for the Clear Lake TMDL.

The CTR criterion is proposed as a secondary target for the TMDL. Regional Board staff intends that implementation of the TMDL will result in compliance with the CTR criterion. Regional Board staff, however, does not consider the CTR value to be sufficiently protective of humans consuming fish from Clear Lake. The CTR value was determined using bioaccumulation factors that are lower than those believed to apply to Clear Lake. The CTR encourages the use of site-specific information for bioaccumulation factors.

9. **Page 3:** It is stated that “the acceptable daily intake value is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects.” The report uses “acceptable daily intake” and “reference dose” interchangeably. The National Academy of Science report issued in the summer 2000 states that “A reference dose is defined as an estimate of a daily exposure to the human population (including sensitive sub-populations) that is likely to be without a risk of adverse effects when experienced over a lifetime.”

“Acceptable daily intake” was intended as a generic term that would encompass reference dose and other equivalents, such as ATSDR’s Minimal Risk Level. The concept of reference dose was explained in this way, because not all agencies call their safe levels “reference doses. The text has been changed to a more consistent use of the term reference dose.



**10. Is it the intent of the Regional Board to adopt a mercury target which has zero risk of adverse effects to sensitive individuals? How can the risk associated with the proposed mercury target be better quantified? Is the concept of “full protection” associated with some quantifiable level of risk?**

Although non-carcinogens, such as methylmercury, demonstrate threshold levels of effects, a “zero level” of risk is very difficult to define. For non-carcinogens, USEPA uses a reference dose approach. The reference dose is an estimate of dose that is likely to be without an appreciable risk of deleterious effects during a lifetime, including sensitive subgroups. Regional Board staff is proposing a target that is based on the average consumption rate of a relatively high-consuming subpopulation and the USEPA reference dose. The 60 g/day consumption rate and the 10-fold uncertainty factor in the RfD produce a fish tissue target that Regional Board staff believes is protective of consumers of Clear Lake sport fish. Regional Board staff is not attempting to define risk further. We are not aware of a method of assessing risk for non-carcinogens that is comparable to the “one-in-a-million” type of assessment done for carcinogens.

**11. Page 3: At numerous locations in the draft report, reference is made to a mercury fish tissue target which is protective of humans, in general. Isn't it more precise to say that the proposed fish tissue target of 0.1 mg/kg is protective of the developing fetuses of women who consume 60 grams per day of fish during pregnancy? Relatedly, isn't it accurate to say that the fish tissue target to protect adults or children consuming 60 grams of fish per day would be expected to be 3 to 4 times higher (e.g. 0.3 to 0.4 mg/kg) (see page 18 of the Draft report and page 95 of the NAS report) The NAS report notes “there are clear differences between fetal and adult MeHg neurotoxicity” (IPCS (1990) and Gilbert and Grant-Webster (1995). The NAS report also states that effects in prenatally-exposed children appear at intake levels which are five to ten times lower than intakes associated with toxicity in adults.**

The revised USEPA reference dose upon which the target is based is intended to be applied to the general population. It is not specifically a reference dose for developmental toxicity. Therefore, the target is described as protective of humans in general. In revising the reference dose, USEPA evaluated human health studies that suggest that adverse immunological, cardiovascular and chronic neurological effects occur in adults at mercury levels below those causing acute neurological effects. Threshold levels for these effects in adults have not yet been determined.

We have tried to be very clear in the report about the assumptions used in developing the target, and have explained the assumptions before the calculation of the target.

**12. Page 3: The draft report states that the USEPA reference dose of 0.1 ug/kg bwt/day and the ATSDR minimal risk level of 0.3 ug/kg bwt/day are each acceptable options for use in the TMDL. The report goes on to select the USEPA value as the single value for use in target selection.**

As explained in the text of the report, the USEPA and ATSDR values are acceptable options because they are based on critical effects in children exposed during pregnancy, as opposed to the FDA value, which is not. More complete rationale for selecting the USEPA RfD instead of the ATSDR MRL has been added to the main text (See response to comment 38).

- 13. If the target based on the EPA RfD is “protective”, is a fish target based on the ATSDR minimal risk level “not protective” or “insufficiently protective”? Our reading of the NAS report indicates that the scientific experts found use of the EPA RfD to be scientifically valid, but did not comment directly on the scientific validity of the ATSDR minimal risk level. Similarly, the draft report does not explain the elimination of the ATSDR value from consideration, other than reliance on the NAS finding which supported use of the USEPA value.**

Justification for selecting the USEPA RfD instead of the ATSDR MRL has been explained more fully in the main text

- 14. Page 4: The fish consumption rate for Clear Lake proposed in the draft report of 60 grams per day is based on the 1992 fish consumption survey of the Elem Indian Colony. The report does not address (a) the percentage of the overall Clear Lake population represented by the Elem colony, (b) the sufficiency and reliability of the methods used in the Elem fish consumption study, (c) the number of pregnant women included in the Elem study, (d) the specific species of the “catfish” and “perch” reported in the study, and (e) the sizes of fish reported.**

(a) According to the Lake County Visitor Center, the 1990 Census figure for Lake County is 55,700. The 2000 population figure is estimated to be 56,000. Participants in the Harnly study represent approximately 0.11 % of the total population of Lake County. The missing piece of information, however, is consumption patterns by other residents. Fishing by residents and visitors is a popular activity at Clear Lake. (b). Methods of the Harnly study, including recall period, have been discussed more fully. (c). Number of pregnant women interviewed is unknown. More information has been added. Please see response to comment 49. In order to encourage participation, the interview was brief. Information on size of fish consumed was not obtained.

- 15. Page 5: In summarizing the estimated intake rates for a hypothetical “human consumer”, it would seem appropriate to substitute “child bearing woman” into the sentences where the word “human” is used, to be more precise regarding the predicted affect. The acceptable daily intake values used in the comparison are derived from and strictly related to child bearing women. While it is accurate to say that use of targets protective of unborn children would also be protective of adult consumers, it is not accurate to use the acceptable daily intake rates in a predictive fashion for all humans.**

We have clarified the population to which the reference dose may be applied. The USEPA reference dose is based upon the critical effect of neuropsychological impairments in children exposed both prenatally and post-natally to methylmercury. One area of concern that was supported use of a composite uncertainty factor of 10 for determination of the RfD, was lack of

data on long-term sequelae of childhood exposure. Follow-up studies of the Minamata population indicate that neurological dysfunction among people exposed to methylmercury become more pronounced with aging. According to USEPA, "...there are currently no data that would support the derivation of a child (vs. general population) RfD. This RfD is applicable to a lifetime daily exposure for all populations including sensitive subgroups. It is not a developmental RfD per se, and its use is not restricted to pregnancy or developmental periods." (USEPA, 2001). Regional Board staff, therefore, has used the USEPA RfD to apply to the entire human population.

## **Introduction**

**16. Page 6:** First sentence, it is more appropriate to say that mercury may adversely affect humans and wildlife. In fact, the NAS report states that "the risk of adverse effects from current MeHg exposures in the majority of the population is low." The NAS report also notes that individuals with high MeHg exposures from frequent fish consumption might have little or no margin of safety (i.e. exposures are close to those with observable adverse effects).

Mercury has been documented to cause adverse effects to humans and wildlife (e.g., [Thompson, 1996 #11; Marsh, 1987 #89; NRC, 2000 #64. Occurrence of toxicologic effect is dependent upon dose. The text has been changed to read, "Mercury is a widespread environmental contaminant. In some waterbodies, mercury concentrations may reach levels that adversely affect humans and wildlife."

**17. Page 6:** The report states that the purpose of the document is "to describe the derivation of water quality targets that are designed to protect beneficial uses of the water and resources of Clear Lake, California by humans and wildlife."

**Are targets viewed by the Regional Board to be equivalent to water quality objectives in terms of (a) level of protection, (b) enforceability, (c) derivation methodology or (d) formal process for adoption under Porter Cologne. It would appear that they will be used in the TMDL process in the same way as adopted water quality objectives. That is, targets will be used to mark the success (or failure) of the TMDL implementation plan. Also, since the purpose of TMDLs is to bring waters into compliance with standards, targets themselves must either be (a) a standard or (b) a numeric interpretation of a standard (which arguably is a standard itself).**

**Does the Regional Board intend to use the USEPA Use Attainability Analysis procedure as a mechanism to address the fact that the proposed target may not have been attained in Clear Lake since 1975? If so, how does the Regional Board intend to do this. The report should provide the reader some insights into this process and how it will work.**

Regional Board staff will propose that the Regional Board adopt as water quality objectives those numeric targets that identify the ultimate goal for a particular contaminant (in terms of beneficial use protection). Regional Board staff may also propose that the Regional Board adopt other numeric targets that serve as indicators of progress in achieving the ultimate water quality

objectives (e.g. targets for other media or interim targets) or targets that aid in relating implementation actions to attainment of the water quality objective (e.g. source specific and total mass loading targets).

Regional Board staff may apply a Use Attainability Analysis procedure (as defined in 40 CFR § 131.10) should an evaluation of implementation options indicate that the uses could not be reasonably attained (as defined in 40 CFR § 131.10(h)(2) and Porter-Cologne). It should be noted that both the Clean Water Act (Section 101(a)(2) ) and the Porter-Cologne Water Quality Act (Sections 13000 and 13241) appear to be urging the maximum reasonable protection of the State's waters and not just to improve water quality to 1975 levels. Federal Regulations (40 CFR § 131.3(e) ) require State's to minimally designate uses for protection that were attained on or after November 28, 1975, when performing a use attainability analysis. Regional Board staff will recommend protection of uses that were attained prior to that date should such protection appear reasonably achievable.

**18. Page 6: It is noted that consumption of “highly contaminated fish” has caused a number of severe effects in humans, referring to several past studies. It should be clarified whether the levels of mercury in Clear Lake fish reach the levels observed in these other cases. The report should present past and present data (i.e. 1970 to present) in tables or an appendix to compare tissue concentrations for various species to the levels observed in severe contamination episodes and to the proposed target for Clear Lake.**

Concentrations of mercury in fish from Clear Lake have been added in Appendix A.

**19. Page 6: It is noted that children whose mothers ate fish during pregnancy or who eat fish themselves may be at risk for more subtle behavioral and developmental changes. Our reading of the NAS report indicates that the USEPA reference dose is not based on exposure from children eating fish. Please clarify or provide support for this statement.**

You are correct that the USEPA reference dose is based on exposure of the unborn child during pregnancy, not on exposure to children after birth. Support for the statement that young children who eat contaminated fish themselves may be at risk for subtle neurobiological effects comes from several sources. In a summary/review article, a primary author of the Mercury Study Report to Congress writes that after the mother/fetal pair, the second group most likely at risk is young children, particularly those younger than six (Mahaffey, 1999). Concern for young children is increased over that of adults for two reasons: 1) young children tend to consume more fish per body weight than adults (USEPA, 1997d). 2) young children may be more vulnerable to mercury toxicity because their neural systems are still developing. A study of Amazonian children ages 7-12 living downstream of gold mining activity linked subtle neurotoxicity with mercury exposure. The authors concluded that although prenatal exposures were unknown, mercury consumed by the children seemed sufficient to cause the adverse effects (Grandjean et al., 1999). From a practical standpoint, in recent studies of children in the Faroe and Seychelles Islands and other areas, effects of exposure to mercury in utero are difficult to

separate from exposure through fish consumption by children themselves, when evaluations are conducted beyond infancy. The text has been clarified and corresponding references added.

- 20. Page 7:**           **The draft report states that wildlife species exhibit detrimental effects from mercury exposure and that reproductive impairment has been observed in several species. It is requested that clarifying language be added to indicate that no adverse effects due to mercury have been observed in studies performed on Clear Lake wildlife.**

Text and references to Clear Lake have been added.

- 21. Page 8:**           **It is stated that unacceptably high levels of mercury are present in some streams and lakes in the Sacramento River watershed and the Delta. Is the California Toxics Rule standard for mercury in water used to establish the threshold for unacceptability? What numeric value is used as the basis for this finding?**

The basis of this statements was not a quantitative evaluation, but refers to the number of waterbodies listed as impaired due to mercury on the 1998 Clean Water Act 303(d) List of Impaired Waterbodies. Waterbodies have been placed on the 303(d) list following the issuance of fish consumption advisories and/or because of exceedance of drinking water quality standards. The California Toxics Rule was not available for listings made prior to and for the 1998 303(d) List.

- 22. Page 9:**           **It is stated that Clear Lake is on the Clean Water Act 303(d) list based on the existence of a fish consumption advisory issued in 1987 by the Department of Health Services. Is a primary goal of the TMDL process to eliminate the fish consumption advisory for Clear Lake?**

Yes. A primary goal is to reduce levels of mercury in fish sufficiently, so that fish consumption advisories are no longer needed. Advisories are established by California Office of Environmental Health Hazard Assessment. It would be up to OEHHA to remove the advisory.

- 23. Page 10:**   **In Table 2, likely impairment of four uses is noted. Please provide the basis for the finding that Warm Water Fish Habitat and Spawning are likely to be impaired in Clear Lake by mercury.**

Table 2 has been changed to indicate that “Sport/Recreational Fishery” and “Wildlife Habitat” are potentially impaired by mercury.

- 24. Page 11:**   **Clarification is needed to define when “impairment is eliminated and beneficial uses are protected”. Does this imply that all numeric targets must be attained, or that all advisories must be removed? The draft report should be definitive on this point to educate the public regarding the significance or the target selection to the future TMDL-driven activities.**

A clearer definition of a TMDL has been provided. More detail and clarification is provided in the Introduction under the new section of “TMDL Timeline for Clear Lake”. Regional Board staff anticipates that an implementation plan will include public education.

- 25. Page 11: The requirements which the Regional Board must meet under the Porter Cologne Act should be clearly described. It should be clarified that the State is charged with reasonable protection of beneficial uses and that water quality objectives must be adopted as amendments of existing Basin Plans.**

The requirements that the Regional Board must meet under the Porter-Cologne Water Quality Act are described under sections 13000, et. seq. A general description of this process is given in the mercury numeric target report for Clear Lake.

### **Selection of Type of Target**

- 26. Page 12: The assessment of the use of tissues from other biota (e.g. human blood or hair, bird feathers or eggs, mammal blood) as targets should mention potential advantages in addition to the listed disadvantages. Advantages are that such measurements provide a more direct linkage to the basic research from which reference doses have been derived and are better indicators of fish consumption than anecdotal recall. The NAS study indicates that samples of human blood and hair are both valuable tools for evaluating mercury exposure. Both are used in the analysis to correlate exposure with effects. The best correlations are observed between mercury blood concentrations and effects. Regarding hair analysis, the NAS report states “...hair Hg concentration as a biomarker of MeHg exposure has the advantages of being able to integrate exposure over a known and limited time and recapitulate the magnitude and the timing of exposure...Despite...limitations, hair samples have the potential to provide temporal information on Hg exposures.”**

Additional information on blood and hair biomarkers has been added to the text. Measurements of mercury in hair and blood do provide good estimates of mercury exposure. They are extremely useful, as you point out, to link basic research with observations in a potentially exposed population. The target used in the TMDL, however, needs to be a measurement that has a good baseline and is representative and repeatable, in order to monitor progress of implementation of the TMDL. Establishing baselines and repeat measurements of hair and blood in a statistically valid subpopulation of humans would be both technically and logistically difficult. Identification alone of a stable, representative subpopulation willing to participate repeatedly in testing would be extremely challenging.

- 27. Page 12: It is stated that analysis of eggs of nesting birds provides a valuable tool for evaluating effects of mercury on reproduction. This should be modified to say that eggs may provide such a tool, since essential information is lacking regarding threshold effect levels for Clear Lake species.**

Level of mercury in eggs has been used as a bioindicator of reproductive effects in other settings (Thompson, 1996, Wolfe, 1998 #43). It is likely that this would hold true for birds utilizing Clear Lake. The text notes that existing baseline concentrations of mercury in eggs and threshold levels are not well known for avian species of concern at Clear Lake.

**28. Page 13: The San Francisco Bay TMDL report for mercury suggested that mercury levels in sediments must be reduced before water column objectives can be achieved. Also, it was implied that mercury levels in sediment directly impact mercury levels in fish, on a long term basis. The same fundamental question applies to Clear Lake: Are reductions in mercury concentration in sediment required to achieve reductions in fish tissue concentrations?**

In order to effect substantial reductions in fish tissue levels of mercury, levels of mercury in the active layer of Clear Lake sediments may need to be reduced (active layer refers to the top portion of the sediment in which methylation occurs, or that is resuspended by currents to be possibly methylated elsewhere). This topic will be discussed more fully in the Source Analysis section of the TMDL report. The UC Davis Clear Lake Environmental Research Center is conducting studies, to be completed in Spring 2001, that will help to determine whether dissolved mercury entering the lake is more readily methylated than mercury already present in sediments. A major source of mercury in the sediments is historical operations at the Sulphur Bank Mercury Mine, now a Superfund site. The Regional Board will be working closely with the EPA Superfund Program on the TMDL implementation plan for mercury entering the lake and lakebed sediments.

**29. Page 13: The statement is made that concentrations and transport of suspended sediment in the estuary are relatively well understood. What is the basis for this statement? This was identified as a serious data gap in discussions with the CALFED study team.**

You are correct. There is a large dataset of concentrations of mercury in sediment and water in the Estuary, but sediment transport and remobilization is not well understood. We have changed this statement to specify the data available. We have also revised this section on the SF Bay TMDL sediment target to better explain its justification and assumptions.

**30. Page 13: We suggest use of the term “water quality objective” when referring to the CTR standard of 50 ng/l which applies to Clear Lake (in lieu of the term “criterion”, which may be interpreted as being advisory only).**

In May 2000, the USEPA promulgated numeric criteria for priority toxic pollutants for the State of California (California Toxics Rule; CTR). Criterion is actually the correct term for values in the CTR. The term “water quality objective” has a specific, legal definition under the Porter Cologne Water Quality Act. "Water quality objectives" must be reasonable to achieve under Porter-Cologne, whereas "criteria" must protect the beneficial use regardless of achievability under the federal Clean Water Act. The CTR and NTR "criteria" plus the beneficial use

designations in the Regional Board's Basin Plan form enforceable water quality standards under the Clean Water Act.

- 31. Page 13: Water column data for Clear Lake from 1994 to 1996 is cited. Were clean sampling and low detection limit analytical methods used in the collection of these data? Do these data indicate a spatial trend in total mercury concentrations, with all elevated levels observed in Oaks Arm?**

Subsurface and surface samples of water were collected using "ultra-clean" techniques that are standard in the scientific community, to avoid contamination of samples. Deep water samples (0.5 – 1.0 m above the sediment water interface) were collected using a peristaltic pumping system with Teflon tubing. Surface samples were grab samples collected about 0.5 m below the surface. Samples were analyzed by Battelle Laboratories, with detection limit of 0.1 ng/L for total mercury. (Suchanek et al., 1997, verified by personal communication with Dr. Suchanek). Concentrations of mercury in unfiltered water declined as a function of distance from the mine. Samples with concentrations greater than the CTR criterion were collected from Oaks Arm and less frequently from the Narrows (4 data points over approximately 10 years of sampling) and Lower Arm (one data point over the same period).

- 32. Page 13 A formula for calculating the water column target is provided. We recommend that an example calculation be provided using values for mercury fish tissue concentration and bioaccumulation factor. This would provide an estimate of the water column target prior to development of site specific bioaccumulation factors. The report should also state when the site specific bioaccumulation factors will be developed and how they will be used to reach water quality targets.**

We deliberately did not provide a sample calculation, because we did not yet have bioaccumulation factors specific to Clear Lake. Bioaccumulation factors for mercury vary widely in published literature, in some cases by one to three orders of magnitude. It would have been potentially misleading to assume one factor for the sample calculation, only to change it in the draft final TMDL report. Site-specific bioaccumulation factors are expected to be provided in Spring 2001, by UC Davis Clear Lake Environmental Research Center.

- 33. Page 14: The details of the fish consumption study for the Elem Indian Colony should be included in an appendix to the report and summarized in more detail in the report. Information regarding the study methodology, study results, and blood and hair data should be included.**

All details of the study by Harnly and colleagues that were used in this document were obtained from their published paper (Harnly et al., 1997). We have added results of the hair and blood measurements in the text and in Appendix B. We believe that the paper is sufficiently summarized in this report. Regional Board staff will provide the Sacramento Regional County Sanitation District with a copy of this paper, if needed.

- 34. Page 14: The report cites poor correlations between mercury levels in water column and levels in biota. These data should be summarized in an appendix to the report.**



The reader is referred to the references by Suchanek and colleagues [Suchanek, 1993 #52; [Suchanek, 1997 #42. These data collections on mercury concentrations in Clear Lake span over five years.

- 35. Page 15: The calculation of bioaccumulation factors for the Clear Lake TMDL should be included in this report to illustrate the impact of proposed fish tissue target decisions on potential water column targets.**

Site-specific bioaccumulation factors and calculations of associated water column values will appear in the draft final TMDL report. Site-specific factors were not available for the draft Numeric Target Report. Please see the response to Comment 32.

### **Potential Human Health Targets**

- 36. Page 15: It is stated that a goal of the Clear Lake TMDL process is to reduce risks to humans and wildlife. How will baseline risk be quantified to allow an assessment of a change in risk?**

This section of the report, and the section titled “Comparison of human and wildlife potential targets” essentially lay out the method for determining existing risk. A simple way of determining risk is to calculate existing exposure for a hypothetical consumer, and to compare that with the acceptable level of exposure. This is the same method used by Office of Environmental Health Hazard Assessment in determining the need for fish advisories (OEHHA, 2000) and is recommended by USEPA (USEPA, 1995c). For humans, the accepted level of exposure used here is the USEPA reference dose. Factors incorporated for calculating potential existing exposure are the same as those needed for determining the target: concentrations of mercury in various fish in the lake, and body weight and consumption rate assumed for a consumer. As shown in Table 9, existing exposure for an adult human eating about two meals per week of fish with three fourths of those meals being top trophic-level fish (catfish), is about 3.3 times higher than the acceptable daily exposure. There is a health risk to people eating this much fish from Clear Lake. Existing exposure can be calculated for other rates and species of fish eaten by humans and for wildlife. Ease of assessing change in risk is a major advantage of using a fish tissue target. Change in fish tissue levels of mercury is directly related to change in risk.

- 37. Page 16-19: Clarification of the basis for the USEPA reference dose is needed in this section. As noted in the NAS report “The population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy”. The USEPA reference dose is derived from the Faroe Island study of developmental effects in children of women who consumed specific levels of fish (whales) during pregnancy. The report should state that this reference dose is not predictive of adverse impacts on adults or children consumers.**

The basis and applicability of the USEPA reference dose (RfD) have been clarified in the report. The reference dose referred to in the draft Numeric Target Report was issued by USEPA in

1995, and was based on data from the Iraqi poisoning episode. In December, 2000, USEPA issued a revised RfD that is based upon the Faroe Island Study.

The current RfD was developed using the lowest known toxicity threshold, that of adverse neurologic effects in children who were exposed early in development. In the Methylmercury Water Quality Criterion document, however, USEPA is careful to point out that the 2000 RfD is not a developmental reference dose. It describes a level of exposure to methylmercury that will not cause extra risk in the general population, over a lifetime of exposure.

**38. Page 17: The basis for not retaining the ATSDR reference dose as an option in the target selection process should be clearly explained. The NAS study supported the USEPA reference dose, stating that the value of EPA's current RfD of 0.1 ug/kg per day is a scientifically justifiable level for the protection of human health. However, the NAS expert panel was not charged with the calculation of a definitive RfD and did not state that the ATSDR value of 0.3 ug/kg/day was not "scientifically justifiable".**

**The NAS report describes the methods used in deriving the USEPA RfD value. As noted in the NAS report, "A reference dose is defined as an estimate of a daily exposure to the human population (including sensitive sub-populations) that is likely to be without a risk of adverse effects when experienced over a lifetime." The USEPA RfD was calculated from the Faroe Island study using data for the most critical endpoint and most sensitive consumer group, and applying an uncertainty factor of 10 to the benchmark dose level (which approximates the lowest observed effect level). The NAS panel supported use of an uncertainty factor of at least 10 to calculate an RfD value which would predict zero risk of adverse effect. The NAS panel noted that the selection of the uncertainty factor was, at least in part, a policy decision (the uncertainty factor related to "data insufficiencies" was in the range of 2 to 5). That policy decision involves an unstated and un-quantified risk management decision.**

**It is requested that the target report address these considerations. It would seem that the Regional Board would have flexibility to consider options to the USEPA RfD in setting a TMDL target.**

Additional discussion of the ATSDR and EPA values and selection of the EPA RfD has been added to the text. Please see response to Comment 37 regarding the basis of the EPA RfD.

A composite uncertainty factor of 10 was selected originally by EPA scientists and upheld by those on the independent National Academy of Sciences committee. At the State level, our sister agency that deals directly with public health risk assessment, the Office of Environmental Health Hazard Assessment, is continuing to use EPA's benchmark dose and uncertainty factor. Regional Board staff believes that it is appropriate to use a RfD consistent with that used by the two agencies that deal most directly with mercury-related health risks in California. It may be that in adopting the TMDL as a Basin Plan Amendment, members of the Regional Board will direct staff to use different uncertainty factors.

- 39. Page 19:** It is stated that acceptable daily intakes for men and women not intending to have children are 3 to 5 times higher than the USEPA RfD. This implies that the USEPA RfD is derived from studies of all women of child bearing age, not just child bearing women. Our reading of the NAS report indicates to the contrary, that the USEPA RfD is based on an evaluation of women who have eaten fish during pregnancy, rather than on women with a life history of a given level of fish consumption. The NAS report states that “The mean half-life of total MeHg in blood in humans is about 50 days (Stern 1997; EPA 1997), but much longer half-lives (more than 100 days) are observed”. This would indicate that short-term mercury exposure is the relevant issue in assessing risk to unborn children.

The study underlying the EPA RfD examined associations between neurologic impairments in children with estimates of methylmercury intake by their mothers during pregnancy. This point has been clarified in the report.

Both EPA and OEHHHA express particular concern for pregnant and nursing women and women who may become pregnant that eat contaminated fish, not just for pregnant women (OEHHHA, 2000; USEPA, 1999a). The agencies do this because generally a fetus develops for several weeks before a woman is aware she is pregnant, and because mercury bioconcentrates (a half-life of 70 days in human blood means that half of the mercury absorbed in one meal is in the body over 2 months later). Short-term, peak exposure are definitely important in assessing risk to unborn children (Mahaffey, 1999). There is likely a critical period in development during which the fetus is most vulnerable to adverse effects, but timing of this period is unknown. An education program based on the existing fish advisory or TMDL should clearly explain which portions of the population are at risk at given levels of fish contamination. Risks of adverse effects do occur, however, throughout the lifetime of a person eating contaminated fish and mercury does bioconcentrate. As a starting place for the TMDL, we are using a RfD derived for a lifetime of exposure. This is the standard approach used by both EPA and OEHHHA.

- 40. Page 19:** It is stated that any option considered for the TMDL must be “fully protective of humans”. If this terminology is to be used, it must be clearly defined. Also, the relationship of this statement to prior statements regarding adjustments of the target after consideration of economics and technical feasibility must be clarified.

The language in the target report has changed. References to terms such as “protective” or “fully protective” are made in the context of the qualifications of “attainability” and “reasonableness” used in the federal Clean Water Act and state Porter-Cologne Water Quality Act, respectively.

- 41. Page 23** The last paragraph indicates “There are quite likely consumers at Clear Lake that also eat greater than 60 g/day”. It should be noted in the report that most of the population is expected to consume *less* than the 60 g/day based on consumption studies other than the Elem Indian Tribe survey. The text also indicates that several consumption studies conducted in California and nationwide have shown higher consumption rates. Of the studies listed in Table 5 only two out of the ten listed indicated a consumption rate average higher than 60 g/day. Please clarify if the text is

**referring to values other than the average such as the 95<sup>th</sup> percentile or other studies that are not included in this report.**

As shown in Table 3, averages of fish consumption derived from national surveys are lower than the average reported by members of the Elem Nation. Regarding risk, we are concerned about the people who have relatively high consumption rates. Studies with consumption rates greater than 60 g/d (both averages and higher percentile values) have been expanded upon in text after Table 3.

**42. Page 22 - 28: It is stated that fish consumption data used in the development of criteria should only be derived from surveys of regular consumers of fish. This is in contrast to criteria development methods used to date by USEPA, which have used average consumption rates. The fish consumption rate proposed in the draft report (60 grams per day) is significantly higher than rates recently used by USEPA in setting regulatory levels for mercury in non-marine fish tissue. USEPA has used 6.5 grams per day (US average per capita consumption of non-marine species) in setting the May 2000 human health-based mercury standards in the California Toxics Rule. This difference raises a question regarding the Regional Board's determination that use of averages which include non-consumers is mandatory.**

**In the California Toxics Rule Preamble, USEPA discusses the relative risk ramifications associated with average versus high exposure individuals in setting human health-based water quality standards. Clearly, standards set based on people who consume fish at average rates will not provide equivalent protection to people who consume fish at higher rates. A balance must be reached between setting extremely stringent standards based on high-end exposures and setting standards that are not adequately protective for most exposed individuals. A more complete discussion of this issue is required before a fish consumption rate can be selected.**

For the California Toxics Rule, USEPA actually used a slightly higher consumption rate of 18.7 g/day for calculation of the mercury criteria than was used for other bioaccumulative constituents (see the Federal Register notice of the proposed CTR, verified by personal communication with Diane Fleck of USEPA on 13 Sept., 2000) (USEPA, 1997e). When the final CTR was released, EPA was in the midst of review of its human health criteria, including consumption rates. A revised Methodology for Deriving Water Quality Criteria for Protection of Human Health has since been released (USEPA, 2000b). In the new Methodology, EPA recommends a default fish intake rate of 17.5 g/day to adequately protect the general population, which was based on the 1994-96 USDA Continuing Survey of Food Intake by Individuals. This value represents the 90<sup>th</sup> percentile consumption for all survey participants, including those who don't eat fish. The EPA recommends a default fish intake rate of 142.2 g/day for subsistence fishers, based on consumption of fresh/estuarine fish only (not marine fish). According to the new Methodology,

...because the level of fish intake in highly exposed populations varies, EPA suggests a four preference hierarchy for States and authorized Tribes to follow when deriving consumption rates that encourages use of the best local, State or regional data available. ...EPA strongly emphasizes that States and authorized

Tribes should consider developing criteria to protect highly exposed population groups and use local or regional data over the default values as more representative of their target population groups(s). The four preference hierarchy is: (1) use of local data; (2) use of data reflecting similar geography/population groups; (3) use of data from national surveys; (4) use of EPA's default intake rates. ...States and authorized Tribes may use either high-end values (such as the 90<sup>th</sup> or 95<sup>th</sup> percentile values) or average values for an identified population that they plan to protect. *USEPA, 2000b pp. 4-25 and 4-26*

As indicated by above language in the revised human health criteria Methodology, selection of a locally-derived consumption rate is therefore clearly within bounds of EPA recommendations. The above information has been added to the report text.

The Regional Board has not determined that it is “mandatory” to use consumer-only consumption rates in determining the numeric target. It is logical, however, to use consumption rates for people potentially at risk from toxic effects of mercury in fish, i.e., those who eat fish or seafood. Previous reports issued by OEHHHA show support of the use of consumer-only data to develop water quality criteria (Gassel et al., 1997).

- 43. Page 22: We agree that the selection of a fish consumption rate as the basis for the fish tissue target is a difficult decision. Many factors enter into this selection, including the percentage of the overall population which consume fish at the target rate, the species and size of fish consumed, the methodology for determining fish consumption rates, the consumption rates of marine fish versus locally caught freshwater fish, fish consumption rates by child bearing women, etc.**

We agree that the many factors you have listed have bearing on the fish tissue target, and that it is a complex decision. We have tried to address as many of these factors as possible in the target report. Where we are lacking information, such as a more comprehensive fish consumption survey for the Clear Lake basin, we have made assumptions and used information that appears to be most relevant to derivation of a mercury fish tissue target.

- 44. Page 23: Table 3 is titled “Representative Seafood Consumption Rates”. Rather than calling these rates “representative”, it seems these should just be classified as rates reported in other studies. Also, a delineation should be made between rates of seafood consumption (defined as ocean-caught fish or shellfish) as opposed to locally caught (estuarine or fresh water fish or shellfish), since the Clear Lake TMDL will only address the mercury in locally caught species. The table should clearly separate total fish consumption rates from locally caught (non-marine) consumption rates.**

The title of Table 3 has been changed. Notation has also been added as to whether the data reported is for consumption of commercial, locally-caught, or both.

- 45. Page 23: How is the difference in fish consumption rate in US women ages 19 –50 as reported by Popkin et al (1989) (111 grams per day) and the consumption rate reported by USEPA (1997) in US women aged 19-44 (9 grams per day) explained. The mean rate cited by Popkin is approximately twice the mean or median rates cited in other studies.**

**This is an important point, since women in these child-bearing ages are the target group for the proposed mercury target.**

As noted in Table 3, Popkin and colleagues estimated the amount of fish and seafood consumed in mixed dishes, such as seafood salad, casserole or chowder. The same national surveys were analyzed by Pao and coworkers, who did not estimate consumption from mixed dishes. In their review of these two papers, OEHHA staff commented:

Whether this difference in methodology accounts for most of the disparity in results is difficult to ascertain. Estimates of consumption that include fish and shellfish consumed in mixed dishes are likely to be more realistic than estimates which do not include this source, although the reliability of the results depends on how accurately the portions of fish and/or shellfish consumed in mixed dishes are estimated. (*Gassel et al., 1997*)

In a new paragraph discussing nation-wide surveys, I have attempted to clarify the difference in results.

**46. Page 24: The soon-to-be released results from the San Francisco Bay fish consumption study should be included in this section, when available.**

We agree. The final report of this study is expected to be released to the public by February, 2001. We will incorporate results on the San Francisco Bay study into the TMDL as soon as the final report is available.

**47. Page 25: The fish consumption study for the Elem Indian Rancheria in Clear Lake relied on recall by participants regarding fish consumption over a previous six month period. Most consumption surveys rely on recall periods ranging from several days to one week. The report should address the quality of the information provided by the Elem Rancheria study. Long recall periods inherently would provide less reliable results than studies with a more typical recall period.**

**Additionally, the Elem Rancheria study included blood and hair sampling and testing. The target report should summarize the results of that portion of the study and provide some analysis of the potential health implications (if any) that can be derived from the hair and blood results.**

We agree that there is potential for recall error when participants are asked to report fish consumption over a 6 month period. In national food intake surveys, participants are typically asked to recall consumption for a month or less, prior to the interview. However, recall of consumption over a longer time period can provide valuable information. In the San Francisco Bay Seafood Consumption Survey, participants were asked to recall consumption for the four weeks and the entire year prior to the interview. Consumers that kept a daily food diary were also asked to recall from memory their consumption over a period of a month or more. This test suggested that high consumers tend to under-report during verbal recall, in comparison with their actual consumption recorded daily.

The data from mercury analyses in hair and blood are shown have been added in Table 6 and in greater detail in Appendix B. We also added a Margin of Exposure (MOE) analysis, to compare the biomonitoring data with benchmark dose levels in hair and blood. The MOE indicated that the Elem Tribal Members and neighbors who participated in the study are potentially at risk for adverse effects of mercury.

**48. Page 25: The hypothetical example cited addresses a person eating only largemouth bass. The results in Table 4 indicate that catfish or perch were reported in large quantities, and would be better species to use in the hypothetical example. The consumption rates of largemouth bass reported in the Elem Rancheria study were quite low.**

We agree that catfish would be a better species to use to estimate the intake of mercury by an adult consuming 60 g/day of top trophic-level fish. Members of the Elem Tribe reported eating little largemouth bass. In addition, we have learned that the largemouth bass fishery throughout the lake is primarily catch-and-release (Bairrington, 2000; Cannata, 2000). Table 6 has been so changed.

**49. Page 26: Can better information be obtained regarding the actual species which were reported as “catfish” and “perch”? This would improve the estimates of actual mercury intakes from Clear Lake fish.**

We have attempted to contact the California Department of Health Services staff who authored the report and members of the Elem Tribe regarding this point, but, have not yet received a response. To get a better interpretation of likely species described as “catfish” and “perch”, we spoke with Steve Cannata, (Department of Fish and Game) and staff of the UC Davis Clear Lake Environmental Research Center, who are familiar with species in the lake and have interacted with many people fishing there. “Catfish” most likely includes species of white catfish and channel catfish. Due to past stocking operations, most catfish caught in Clear Lake are channel catfish. The category of “perch” most likely comprised of bluegill and other sunfish species, white crappie and black crappie. A creel survey by Department of Fish and Game conducted in 1988 found that Sacramento perch comprised about one percent of the total catch (Macedo, 1991). This information has been added to Table 4.

**50. Page 27: A table should be provided which summarizes the typical mercury concentrations of the ten most popular fish and shellfish which are reported in the literature.**

Average concentrations of mercury in the ten most popular types of seafood were listed in the text in the paragraph just before the section “*Recommendations - Consumption Rate*”. This is the most recent information available from FDA.

**51. Page 28: The effort to define “fishable” should address the questions of (a) how much? and (b) by whom? For instance, would different definitions apply to pregnant women as opposed to the remainder of the adult population? These policy decisions must balance reasonable expectations of use with levels of protection and attainability.**

**Clearly, it is possible to set such extreme expectations that the goal of “fishable” would never be attained. Under this scenario, fish advisories would always be in effect and TMDL activities would be never ending. If such a decision was made, it should be clearly articulated in the public forum and the impacts of such a decision should be fully explored.**

The definition of “fishable” for Clear Lake will need to be determined by the Regional Board with the approval of the State Water Resources Control Board and U.S. EPA. Regional Board staff will provide the Regional Board with information regarding reference doses to protect the most sensitive segment of the population, as well as consumption information for various subpopulations. Regional Board staff will also present the Regional Board with information regarding implementation options geared to allow safe consumption for various combinations of consumption rate and population sensitivity to mercury (i.e. pregnant women/ small children vs. non-child bearing adults). The Regional Board must then decide what is “reasonable” and “attainable” as defined under Porter-Cologne and the Clean Water Act.

**52. Page 29: The assumed consumption rate associated with the SFBRWQCB screening value of 0.14 ug/g should be stated in Table 5.**

The table has been revised to include assumptions for all screening values. For the San Francisco Bay fish survey in question, SFBRWQCB used the same consumption rate (30 g/day) and adult body weight (70 kg) as later San Francisco Bay surveys. The reason this screening value was lower than others is because it is based on an older USEPA calculation of a reference dose for developmental toxicity, 0.06 µg/kg bwt/day. It was calculated by EPA by using the mercury reference dose for chronic toxicity established in 1985, 0.3 µg/kg bwt/day, and dividing by an uncertainty factor of 5 to account for greater sensitivity of developmental processes.

**53. Page 30: The proposed fish tissue target for Clear Lake is lower than any of the human health-based target values shown in Table 5. The report should compare this proposed target with actual fish tissue data from Clear Lake to illustrate how levels of mercury in specific fish species in Clear Lake compare to the proposed target.**

We have added a table of fish tissue data from Clear Lake. Please see Appendix A.

**The proposed target should be stated as a fish tissue concentration which would be expected to have no adverse effect on the children of women consuming 60 grams of fish per day.**

Text in the Executive Summary and the human health target section has been revised to clearly explain the assumptions made in deriving the target.

**Alternative fish tissue targets based on (a) the ATSDR minimal risk level and (b) one or several fish consumption rates should be discussed in the report to put the proposed target value into a broader context.**



We have added to the report further explanation for selection of the USEPA reference dose instead of the ATSDR Minimal Risk Level, and for the selection of the consumption rate. One purpose of this document was to describe a scientifically-based numeric target that would be protective of beneficial uses. We also tried to provide a clear explanation of the calculations, in order to allow the reader to make his/her own comparisons.

**Again, the process and timing for considering other factors (economics and technical feasibility) should be fully explained (see previous comment).**

Please see the revised Introduction to the document.

### **Potential Wildlife Health Targets**

**54. Page 31: It is stated that wildlife criteria, in general, tend not to be concerned with survival or health of individuals. We do not agree with this statement. In examining the wildlife criteria for the Great Lakes, no observed effect values and large factors of safety are incorporated into the calculation procedure. No evidence is known to exist which would show that these criteria fail to protect wildlife at the individual level.**

The intent of this paragraph was apparently unclear. Wildlife criteria, are based upon studies that measure effects in individuals that impact the population level. These are effects such as reproductive success, major muscle control and death. Studies of relatively subtle effects that affect individuals have not been conducted for wildlife species. This paragraph has been revised and the following language added: Studies of effects of low levels of mercury in humans have used sophisticated techniques to measure relatively subtle effects on memory, fine motor control and audio-visual function (Davidson et al., 1998; Grandjean et al., 1997). In contrast, studies upon which reference doses for wildlife are based, primarily report effects on reproduction and overt, clinical signs of toxicity, including death (Heinz, 1976; Heinz, 1979; Wobeser et al., 1976a; Wobeser et al., 1976b).

**55. Page 31: It should be noted that the consistency of reference dose values for minks and mallards in the Mercury Report to Congress and the Great Lakes Initiative do not necessarily reflect independent evaluations. Both of these studies were commissioned and overseen by USEPA.**

The following text has been added:

It should be noted that USEPA authored the GLWQI and, several years later, the MRC. Risk assessment methods in the MRC were based upon those in the GLWQI, and expanded to consider potential effects on species in addition to those of concern in the Great Lakes region. The GLWQI effort yielded a final water quality criterion for total mercury in water for protection of piscivorous wildlife. The MRC criteria were calculated using additional information on exposures to methylmercury and dose levels for a wider range of sublethal effects (USEPA, 1997c).

- 56. Page 31: The suggestion that mink may be experiencing decreased reproductive success at Clear Lake is not well supported. Information is lacking on feeding habits and fish consumption rates for minks. Additionally, result of the study by Wolfe and Norman (1998) do not support this suggestion.**

The statement in question comes from comparison of mercury in the diets of laboratory mink, which caused decreased reproductive success (Halbrook et al., 1997; Dansereau et al., 1999), with levels of mercury in fish of the size range to be eaten by adult mink at Clear Lake. This statement has been moved to the section on “Clear Lake wildlife”, to put it in context with the Wolfe and Norman (1998) study. Wolfe and Norman assessed exposure in only eight mink captured at Clear Lake. Given such a small sample size, we cannot conclude that mink at Clear Lake are not at risk.

- 57. Page 32: The applicability (or inapplicability) of the work by Barr (1986) on conditions in Clear Lake should be clearly stated.**

Discussion of Barr’s work with loons and additional information provided by Dr. Steve Schwarzbach and Jim Haas (see USFWS comments in the Response Summary) have been added to the section on Clear Lake wildlife.

- 58. Page 32: It is stated that mercury likely impacts grebe reproduction at Clear Lake. However, it is also noted that grebe productivity at Clear Lake may be impacted by other factors (e.g. boat traffic). The report should include more information to support this statement.**

The paragraph has been revised to clarify and credit the source of the statement. Elbert and Anderson (1998) found productivity of grebes was significantly lower at Clear Lake than at other western lakes not affected by mercury. The authors concluded that mercury is probably not the only cause of the decrease. They noted that Clear Lake has more boat traffic than the other lakes and that boat traffic could disturb grebes enough to impact reproductive success.

- 59. Page 34: In the comparison of human and wildlife targets, it should be clearly noted that these are hypothetical estimates, not well supported by site specific consumption rates.**

We have added the sentences: “Body weight and consumption values were obtained from the USEPA Wildlife Exposure Factors Handbook, a compilation of information on wildlife dietary habits (USEPA, 1993b). These values are averages obtained from various field and laboratory studies and are not necessarily site-specific to Clear Lake (USEPA, 1993b).

- 60. Page 35 and 36: In Tables 8 and 9, it should be stated that exposures and ingestion rates are assumed, not measured. In Table 9, it should be noted that the assumed consumption rate for the estimated exposure of humans to mercury in Clear Lake is based on an assumed consumption rate of 60 grams per day and an assumed mix of fish species (75 percent trophic level 4 fish, 25 percent trophic level 3 fish).**

The ingestion rates were measured in field and laboratory studies. The citation is noted in the text and has been added to the table. See addition to text noted in response to Comment 60. Tables in this report were not intended to be used apart from the accompanying text, which details the assumptions made and the equation used to obtain the exposure estimates. We have added your requested notation to the table.

61. Page 36: **Given the numerous uncertainties and data gaps which exist regarding consumption rates, feeding habits, etc. in Clear Lake, it appears that the key points from the wildlife target section are stated too directly and too affirmatively.**

We feel these are appropriate key points that stand out in the section on wildlife targets. We changed the order of the key points, so that Key Point 1 and Conclusion 1 are now the same (more data needed). We also revised Key Point 2 (wildlife exposures likely exceed acceptable intake) to be more general of wildlife species of concern at Clear Lake, instead of highlighting otter and kingfisher. We added to Key Point 2 the explanation that exposure estimates are based on literature values of consumption and known Clear Lake fish tissue mercury levels.

---

John Demarinis, Water Resource Coordinator, Big Valley Rancheria, Lakeport CA

**Thank you for providing the Mercury Numeric Target Report for the Clear Lake TMDL. The ecological restoration of the Clear Lake watershed is a priority of the Tribe. Tribal members utilize the traditional fish species of the lake for human consumption and cultural activities. The Tribal Leaders are concerned that game species will be the focus of this process and that the investigation may overlook native fishes traditionally used by the Tribe. In addition, Tribal Leaders are concerned for Tribal Members' exposure to mercury levels when disturbing the sediments of the lake during swimming and cultural activities.**

**The Tribal Leaders have a responsibility to protect the human health of the Tribal Members and to protect the natural resources of the Tribe. Thank you for coordinating on the efforts to restore the ecosystem of the Clear Lake watershed.**

Thank you for these comments and for our phone conversation clarifying the species of interest to Tribal Members. You mentioned that traditional aquatic species used by the Tribe include hitch, crappie (often called perch) and crayfish. We have added these species and corresponding mercury concentrations to a table of mercury levels in Clear Lake biota (Appendix A). The study of consumption by Elem Tribal Members did report consumption rates of hitch and perch, which were shown in Table 4. Throughout this target report and in the complete TMDL, we will endeavor to include resources of interest to all Tribes in the Clear Lake watershed.

We would also be concerned about the potential for absorption of harmful levels of mercury from swimming or other contact-related routes of exposure. Mercury measured in deep water samples (one to three feet above the sediment) is consistently below 70 ng/L in the Lower Arm,

below 50 ng/ L in the Upper Arm and is generally below 100 ng/L in Oaks Arm and the Narrows. Peak levels of mercury in the Oaks Arm have been measured at 400 ng/L. These measurements are well below the levels required for safe drinking water. Office of Environmental Health Hazard Assessment has set 1200 ng/L as the California Public Health Goal for mercury in drinking water. This Public Health Goal is adopted just on scientific and public health considerations (not feasibility) and represents the level that would pose no significant risk for a person consuming the water over a lifetime (CVRWQCB, 2000). Toxicology studies of effects of mercury in humans and animals indicate that the form of mercury most readily absorbed is methylmercury. By far, the most significant route of exposure to methylmercury is through consumption of contaminated fish. From this information, Regional Board staff have concluded that exposure to mercury during contact with water or sediment poses minimal health risks and that the focus of the TMDL should be lowering methylmercury in fish tissue. It is assumed that efforts to reduce methylmercury in fish tissue will reduce mercury in water and sediment as well. That said, we do not possess any information on possible adverse effects of transient exposure to methylmercury in water or sediment, or on levels of methylmercury needed to cause adverse effects. Please do not hesitate to bring further concerns or information to the attention of Regional Board staff. The Tribal Leaders' concern about exposure during swimming or cultural activities has been forwarded to Office of Environmental Health Hazard Assessment for response.

---

G. Fred Lee, Ph. D., G. Fred Lee and Associates

**I have reviewed the Draft Clear Lake mercury targets report and find that, overall, its technical content appears to be good. I assume that those more familiar with the literature on wildlife aspects will check to be certain that all the important papers have been covered in this review.**

Reviews have been solicited from US Fish and Wildlife Service and from USEPA specifically for portions of the report related to wildlife.

**Overall, this chapter of the TMDL document is a key part of the ultimate TMDL, in that it establishes an essentially technically valid approach for formulating a TMDL goal. It is going to be interesting to see how the CVRWQCB formulates a TMDL for Hg loads to Clear Lake.**

**The one major technical area that needs to be discussed is the unreliability of trying to contrive a numeric chemical water column concentration objective, where there is an attempt to back-calculate from the tissue residue, a bioconcentration factor. While this approach is the standard US EPA's contrived approach for trying to develop a numeric value which can then be used as a TMDL goal, it is obviously flawed under conditions where the mercury concentrations in the water do not directly relate to mercury concentrations in fish tissue. While it is possible to derive a numeric value with this approach, that value has no meaning except under the specific**

**conditions from which it was derived. Changing the mercury concentration in the water, sediments or loads to the waterbody will require that a new value be developed.**

We agree that there are major uncertainties in calculating a water column target from a fish tissue target using bioconcentration or bioaccumulation factors. We will do our best to reduce uncertainties in the linkage analysis and load allocations by using bioaccumulation factors that are specific to Clear Lake. The CVRWQCB has contracted with UC Davis Clear Lake Environmental Research Center (CLERC) to provide a range and average of bioaccumulation factors for the Clear Lake and for various species. The CLERC report will be available in Spring 2001.

**While mention is made in the report about possibly adjusting the target value considering economic or other factors, an equally valid approach is to change the beneficial uses of Clear Lake, so that it is no longer a warmwater fishery. It is possible that it will be impossible to reduce the mercury content of fish within Clear Lake without horrendous expenditures of funds. Under these conditions, there is a use-attainability issue that could and should be considered as part of developing and establishing the TMDL goal. It is appreciated that telling people that they should not eat fish from Clear Lake will not be protective; however, there may be no alternative.**

Please see response to the Sacramento Region County Sanitation District's comment # 17. Regional Board staff will develop the TMDL and conduct a thorough analysis of feasibility and options along with management of the Sulphur Bank Mercury Mine Superfund Site. It is anticipated that reduction of mercury necessary to meet the target will take some time. Interim targets and continued fish consumption advisories for at least some population groups will likely be part of the implementation plan.

It should be noted that "wildlife habitat" is also a designated beneficial use of Clear Lake. Piscivorous birds and mammals do eat fish from Clear Lake. Estimations using reference doses and consumption data derived from the literature and concentrations of mercury in fish tissue at Clear Lake suggest that some wildlife species there are exposed to mercury levels that exceed safe daily intakes. More data is needed regarding actual effects on Clear Lake wildlife.

**The overall writing style and approach used in this draft report is good, although at some places it does not flow well, and the sentences seem somewhat disjointed. I only saw one obvious typographical error.**

**The major problem with the editing of this write-up is the disregard for proper listing of references. No document should be submitted for review, unless the author has taken the time to properly list all references cited in the text in the reference list and checked to be certain that all references listed in the reference list are cited in the text. The handling of references in this document is extremely sloppy and can readily lead to significant errors in the final document unless someone who understands how to develop and properly check references oversees the development of this document.**

We acknowledge that reference citations were missing from the draft report. We have endeavored to correct all missing and inaccurate citations in the final document.

---

Bob and Mitzi Speirs, Stakeholders, Cache Creek

**Thank you for allowing us to comment on the document. It is an excellent beginning for solving a really tough problem. Hopefully it will be an example for similar TMDLs in other California waterways including all the tributaries entering into the Bay-Delta.**

**The numeric target proposal is going to be a tough sell and it is going to be necessary to convince a great many diverse groups of the need for such an undertaking and the capacity of any procedure to accomplish the goal of significantly lowering risks for mercury poisoning in humans and wildlife. We therefore reviewed the document with the idea of how can it be strengthened and made more convincing to the "doubting Thomases" who for political and other non-scientific reasons may question its necessity.**

- 1. There is a need to clearly define the Mercury Problem from a basic science point of view. Mercury is a poison which has been rapidly increasing (about 1% a year) over the surface of the earth due to natural and anthropogenic activities. It is a cumulative poison that once released into the environment will gradually spread over the surface of the earth, undergoing transformation from one toxic form to another with different solubility and reaction characteristics. For this reason, the report needs to expand the discussion on sources that release mercury and how this release can be modified. The reader should be made aware of the continuous emission of mercury into the atmosphere from a multiplicity of sources and its cycling and recycling between the oceans, land masses and the atmosphere. The primary goal of the TMDL is to reduce mercury emissions into the atmosphere and into the waterways and secondarily to reduce the possibility of its methylation and uptake in the biota. The EPA report to Congress is a good reference to sources. We can FAX you a copy of some of the California sources we have extracted from the report if you would like.**

We agree that public education of the seriousness of the problem of mercury in California waterways can and will undoubtedly occur through the TMDL process. The focus of the target report, however, is to describe possible targets and to detail the process that Regional Board staff used to recommend a fish tissue target. In this document, we basically started with the premise that addressing mercury in general and specifically in Clear Lake is a necessity. For Clear Lake and other waterbodies listed as impaired due to mercury on the Clean Water Act List of Impaired Waterbodies, the Regional Board is required to prepare TMDLs. As you point out, there are good references available that are broader in scope and do a better job of describing the mercury problem than this document. A paragraph has been added to the introduction that specifically directs the reader to these sources for more information. Methods that could be generally applied to reduce the release of mercury are important, but are not within the scope of the target

report. Options for reduction of mercury in Clear Lake will be contained in the implementation plan for that TMDL.

To clarify, the primary goal of the Clear Lake mercury TMDL is not to reduce mercury emissions into the atmosphere. The primary goal of this TMDL is to remove the impairment to Clear Lake waters. Our focus is to reduce mercury concentrations in Clear Lake fish that affect uses of Clear Lake as sport fishery and wildlife habitat. Presumably reductions in mercury in the lake will reduce mercury flux into the atmosphere.

- 2. Mercury has no known beneficial physiological function - its presence in the tissues of living organisms, including man, represents contamination from environmental sources. Exposure to mercury and its compounds can induce both acute and delayed effects, in some cases persisting in brain tissue for more than 20 years after exposure. Mercury produces a multiplicity of adverse reactions within living organisms which at first reading appear random. This is not the case, however. The poisonous action depends in large part on the water and lipid solubility of the mercury compounds and their capacity to complex with intracellular substances. It is certainly true that Hg adversely affects neurological, reproductive and immune systems as indicated in the TMDL report. It also affects the hemopoietic system as well as the integument and gastrointestinal tract. In fact it can penetrate into every cell in the body. The report needs to emphasize how easy it is for the mercury to penetrate into cells and the consequences, especially in embryonic organs and tissues. Mercury complexes with and inactivates intracellular proteins and enzymes containing sulfhydryl (SH) groups. It also reacts with RNA and DNA, resulting in the blocking of normal cellular function. Methylmercury in particular, severely damages tissues which depend on nervous conduction and cell division for activity and growth. Fetal cells are especially vulnerable, appearing to be about 5-10x more sensitive than cells in adult tissues. . One report noted that the brain tissue of mercury-exposed fetuses may be reduced in size as much as 50% at the time of birth. This presentation should make the reader aware that serious consequences can occur following high or prolonged exposure to this environmental poison. The paper given at the UCD 2<sup>nd</sup> annual Clear Lake Science and Management Symposium in October 24<sup>th</sup>, 1998 would be helpful for background information (see "Environmental Mercury - An Immunotoxic Perspective", pages 86-94).**

Thank you for the reference on cell transport and immunotoxicology. It has been added to the report. I have also contacted you directly for references to other review or key papers. Since providing detailed information about the mechanism of action of mercury is considered beyond the scope of this report, we have referred the reader to the additional references.

- 3. It would be useful emphasize the importance of the mercury "buy-back" program as a means of reducing its release into the environment. It only costs a few hundred dollars to buy a few pounds of mercury which released into the environment would cost millions to remove. This may not apply to the Clear Lake area as much as to the Sierra Nevada, but it is possible that local remnants of mercury mining activity are still in existence. If so we should do everything possible to locate and safely dispose of them.**

Regional Board staff will consider this comment as part of our implementation planning for Clear Lake and other Central Valley waters impacted by mercury.

- 4. We agree that human hair would be difficult to use as a numeric baseline to adjust or evaluate a TMDL. (Analysis of fish tissue is certainly the more reliable procedure.) Human hair analysis, along with blood and fecal tests indicate that the person has been exposed to mercury but provides only a rough quantitative index to the level of environmental mercury.**
- 5. We are concerned that determination of safe levels might be based on average amounts of fish eaten per month. This suggests that people who eat more fish than average are less protected or possibly not protected at all. Is it wise to just select a limited population to protect and hope that the others may also receive some limited protection? Would it not be better to choose the most sensitive population and protect at that level, knowing that the less sensitive population would be automatically protected? In setting standards the most sensitive subjects are fetuses, babies and young children. Why not set the limits of sensitivity based upon the fetus within mothers who eat the maximum known amount of fish/month. The biggest problem is that short term exposure within the womb could have "silent" effects which do not become manifest until long after exposure (months or even years). This would automatically mean protection for less sensitive members of the population and those who eat less fish. Public reaction could be strong if it becomes known that fetuses and children are not being considered in setting standards.**

We are also concerned about protecting people who eat more than average amounts of fish. It is true that we used an average fish consumption rate (average consumption reported in a study of Elem Tribal Members) to calculate the 0.1 ppm fish tissue target. In comparison with results of national and regional consumption surveys, 60 g/day (about 2 meals/week) is a relatively high consumption rate. We recognize that there are possibly pregnant women at Clear Lake eating more than 60 g/day. USEPA's reference dose incorporates an uncertainty factor of 10. That is, the safe daily intake level is set at ten times lower than the threshold level for neurologic sequelae to the unborn child. This uncertainty factor provides a margin of safety for persons consuming more than 60 g/day. At this point, we do not know the maximum consumption of fish by pregnant women in the Clear Lake area. Regional Board staff is hoping to receive funding for a consumption survey in the Central Valley, that would provide more region-specific and possibly site-specific consumption information. If consumption surveys and/or new toxicity information indicate sport fish consumers are not adequately protected, we will revise the target. Regional Board staff recognizes it will likely take some time to achieve the target. We will consider whether additional educational activities are needed to protect consumers during the interim.

- 6. The RfD is currently the best index but it will probably be modified by EPA and other agencies as more information is accumulated. Historically the perceived toxicity of a compound has increased over time as we get to know more about it.**



USEPA released its revised RfD in December, 2000. A description of the RfD revisions have been added to the report. If new information suggests the reference dose is not actually a safe daily intake level, Regional Board will revise the target. This point has been added to the report.

- 7. It is certainly correct to select consumers of seafood in estimating intake. The problem is in defining seafood - should you include local freshwater fish? Fish taken from salt water may be different than those taken from fresh water especially in regards to selenium (see item #8). Vegetarians or persons who do not eat seafood or freshwater fish are not subject to the same degree of risk of mercury poisoning.**

As noted on page 22 of the draft report, “seafood” has been used interchangeably with “fish and shellfish”, to refer to fish and shellfish from marine, fresh and estuarine waters. This is consistent with use in consumption surveys. For example, results of national consumption surveys are reported as a total fish consumption of marine (mainly commercial) and sport fish (generally fresh and estuarine). We have tried to be very clear at the points in the report where consumption of locally-caught, freshwater fish is considered separately from commercial fish.

- 8. There is a great deal of published data indicating that coadministration of Selenium reduces the toxicity of mercury. It tends to form high covalency bonds with mercury, reduce its uptake and neutralize some of its adverse effects. Histochemical studies have clearly demonstrated that equimolar amounts of mercury and selenium form complexes with specific proteins and these complexes can persist within the body. Since Clear Lake waters are reportedly low in selenium there could possibly be a local enhancement of the adverse effects of mercury. The cost of adding selenium analysis at the time the mercury levels are determined would be minimal and the results could explain some of the effects observed. I think a review of how selenium reduces mercury uptake and its capacity to complex with mercury within the organism would be in order for this report. It may also suggest procedures for remediation or neutralization of high mercury levels.**

If Clear Lake were enriched in selenium, it might be worthwhile examining adverse effects in wildlife or humans closely with respect to selenium concentrations. Since Clear Lake is not enriched in selenium, we assume we are addressing a problem of mercury alone. It should be noted that the USEPA reference dose for methylmercury was based upon studies of populations consuming ocean fish, which tend to be low in selenium. Selenium exposures to Clear Lake and Faroe Islands residents are assumed to be similar.

- 9. There are a number of ways of determining adverse effects of mercury on fish. One method which would be quick and easy to carry out and does not necessitate killing the specimen is to determine the number of bi-nucleated red blood cells induced by methylmercury poisoning. This has been suggested as a method for monitoring toxicity. A modified method is the use of fish eggs to study the effect of mercury on cell division. Some of these procedures would be far less costly than direct measurement of methylmercury in fish tissue and might be worth considering as a means of monitoring uptake of mercury in the fish.**

Regional Board staff appreciates the references on induction of bi-nucleated blood cells by methylmercury that you have provided. A monitoring method would have to be, sensitive, able to differentiate effects of mercury from other contaminants, and be validated before incorporation into the TMDL. At this time, it appears that further research would be necessary prior to the use of the suggested metric as a numeric target.

**10. Other sources of mercury in humans should not be completely ignored.**

**Methylmercury is particularly important because it is both lipid and water soluble and can readily pass through biological membranes, complexing with intracellular structures. Other forms of mercury, such as ionic mercury, also pass through cell membranes but by a more laborious and selective process of first complexing with membrane receptors. Once inside the cell the reactions are similar and cumulative. Both forms of mercury can undergo further transformation within the cell, eventually depositing as metallic mercury.**

**An important source of mercury which sooner or later must be taken into account is from the amalgams used for dental restoration. There are approximately 200 million mercury tooth restorations per year in US alone. Some reports suggest that humans obtain as much mercury from their fillings as from eating seafood. The mercury released from these filling can pass from mother to offspring through the placenta circulation. The amount that crosses the placenta and becomes incorporated into the fetus has been correlated with the number of fillings of the mother.**

**11. There is also some evidence that intestinal bacteria can transform mercury from one species to another. Ionic mercury fed to animals has subsequently been found to have converted to methylmercury within the body. These transformations ceased following**

We appreciate that humans have other sources of methylmercury and mercury. The Mercury Study Report to Congress performed a thorough evaluation and quantification of sources of exposure to humans (USEPA, 1997b). Authors of the MRC concluded that by far, the primary source of mercury in a non-occupational setting is consumption of contaminated fish. Regional Board staff used this conclusion as a basis for looking only at exposure through fish.

**12. Sooner or later the ingested mercury is released back into the environment and recycles. Cremation is known to be a source of environmental mercury.**

Hospital incinerators, crematoria and chlor-alkali plants are among the industrial operations that can release substantial amounts of mercury to the air. Emissions stack height, mercury species released, precipitation and other factors determine the amount of emitted mercury that deposits locally. There are no major industrial sources of air-borne mercury in the Clear Lake watershed. Our source analysis for the TMDL will likely contain an estimate of air deposition in general.

**13. The report lists beneficial uses of Clear Lake water in Table 2 - but fails to discuss the domestic use and the risks involved. I understand that many communities rely on lake water for their domestic water supply. Is it wise to assume that whatever mercury is in the water used for drinking, bathing and cooking is safe without first analyzing it for mercury content? If the exposure to mercury from eating fish is assumed to be 4x**

**higher than acceptable daily intake, wouldn't a small amount of mercury in the water increase the hazard?**

Levels of mercury in water from Clear Lake have been measured. The UC Davis Clear Lake Environmental Research Center has an extensive database on levels of mercury and methylmercury in raw and filtered water from Clear Lake. Levels of total mercury in samples of water from Clear Lake are two to three orders of magnitude below the drinking water Maximum Contaminant Level of 2,000 ng/L (set by California Department of Health Services). Methylmercury concentrations are generally less than 10 percent of the total mercury concentration in Clear Lake. There are no recommended criteria for methylmercury in water. In both the Mercury Report to Congress and the Methylmercury Water Quality Criterion documents, exposure from various sources was quantified. Estimates of daily exposures to methylmercury through drinking water ranged from  $7 \times 10^{-7}$  to  $6 \times 10^{-5}$  µg/kg bwt/day. Drinking water is estimated to provide less than 0.1 percent of the total exposure to methylmercury. The primary route of exposure is through consumption of contaminated fish (USEPA, 2001).

**14. The report indicated that information regarding mercury content of grebes in Clear Lake is lacking. This is not exactly true. The James Stratton report (Dept Health Services, 1987) indicated that DF&G collected 20 specimens each of coots and grebes from Clear Lake. The coots had no significant mercury accumulation since they were primarily vegetarians. The Grebes which are fish eaters had significantly high mercury levels in the liver and breast muscle which exceeded NAS and FDA guidelines. Similar data was collected from Lake Berryessa and results of the analysis are available (Littrell, E. E. Cal. Fish and Game 1991).**

Department of Fish and Game collected data on exposure of grebes to mercury, which we have added to the report. Still unavailable is information regarding effects of mercury in grebes. Studies have not been conducted that are able to separate possible adverse effects of mercury on reproduction or other activities from effects of disturbance or other contaminants. Department of Fish and Game found average concentrations of 6.4 ppm in liver of western grebe, with a range of 3.7 to 9.8 ppm in birds collected in 1984. Liver of grebes collected by Elbert and Anderson (1998) contained an average of 2.7 ppm mercury. A liver concentration of 5 ppm mercury, wet weight, has been associated with adverse neurologic and other significant effects in waterbirds (Wolfe et al., 1998; Zillioux et al., 1993).

We are not aware of NAS or FDA guidelines for consumption of waterfowl. Presumably, the guidelines for fish tissue were applied to birds. The Department of Health Services report reads notes that grebes are not legal to hunt. They recommended a meal of other fish-eating waterfowl that are legal to hunt be considered equivalent to at least two meals of fish (Stratton et al., 1987).

**15. The data on Bald Eagles is especially interesting since their diet is almost exclusively large fish with relatively high methylmercury content in the tissues of their prey. Do they have a high excretion rate of Hg - via feathers or what? It would be interesting to study the mercury content of Bald Eagles at different times after their arrival from Alaska. This same question could be applied to cormorants, blue heron and osprey. Sometimes it is the exception to the rule that opens the door to understanding.**

Patterns of mercury concentration in feathers of bald eagles and other piscivorous birds is an interesting research question. The review by Wolfe et al., (1998) gives further references about monitoring mercury in feathers. A thorough baseline study of feather levels at Clear Lake has not been undertaken.

**16. The hazardous use of mercury to treat seeds is not just an Iraqi problem. Although no longer permitted, mercury compounds were once widely used in California as fungicides for treating seeds prior to planting. This resulted in widespread death of the birds which dug up the seeds after planting. Because mercury is an element that does not decompose and disappear it continues to exist in one form or another in many of our fields and streams long after the crops have been removed.**

Regional Board staff will consider this comment as we perform source analyses in watershed with significant agricultural land use.

**17. We would recommend that Franco Baldi's paper be considered and referred to. This is in a book entitled: " Mercury and its Effects on Environment and Biology." Edited by Sigel & Sigel, 1997. It is part of a series on Metal Ions in Biological Systems V34. This volume consists of 19 chapters devoted to research areas on mercury, its role in the environment and its effect on life. It is well indexed. Chapter 8 by Franco Baldi is entitled: Biological Transformation of Mercury Species and their Importance in the Biogeochemical Cycle of Mercury. Pgs. 213-258.**

This reference has been obtained and added to the report.

**In summary: Mercury levels in fish should be the primary numeric target for the Clear Lake TMDL. It is certainly reasonable to suggest that if fish levels of methylmercury were reduced to levels that are safe for human consumption, it is expected that wildlife would be protected as well. The safety level should be based on fetal or embryonic sensitivity in mothers who consume relatively large amounts of fish in their diet. Some allowances must be made for the mercury obtained from other sources such as amalgams. This can best be accomplished by using EPA's RfD values with allowances made for high exposures during relatively short periods.**

We agree that the reference dose should be based upon the most sensitive critical effect known, that of neurodevelopmental impairment in children exposed *in utero*. We believe that the 10-fold uncertainty factor incorporated into the reference dose, and use of a relatively high consumption rate to derive the target, provide an adequate margin of safety for persons with additional sources of mercury, such as dental amalgams. Dental amalgams are a significant source to individuals of inorganic mercury, but release almost no methylmercury.

Dr. Steven Schwarzbach and Jim Haas, US Fish and Wildlife Service. Transcript of phone conversation between Janis Cooke and Steven Schwarzbach, 26 Sept. 2000.

1. **Pg. 33 paragraph 1 and Table 9. The acceptable daily intake value for avian species used in the Mercury Study Report to Congress is 0.021 mg/kg bwt/day, not 0.026 as you have typed in your report. This will only change fish levels slightly, but should be correct. I prepared a risk analysis of impacts on mergansers for Chris Foe. The reference dose based on the body weight of mergansers is 0.026 mg/kg bwt/day, - perhaps the source of your confusion. I'll just note for you that to obtain reference doses, authors of the MRC used the Dept. of Energy "Handbook of Toxicity Values for Wildlife" with one change: DOE uses an uncertainty factor of 10, the MRC used an uncertainty factor of 3.**

Section 5.4.4 of Volume 6 of the Mercury Study Report to Congress describes calculation of an avian reference dose of 0.026 mg/kg bwt/day, which was used in that report to determine wildlife criteria (USEPA, 1997c). The MRSC avian reference dose was based upon a low observable adverse effect level of 0.078 mg/kg bwt/day, which was divided by an uncertainty factor of 3 to produce the RfD.

2. **Pg. 33. Table 7. The study by Ruth Elbert on nesting success of western grebes at Clear Lake was fine as far as it went. There are other endpoints that could be examined that would likely give a more definitive assessment of reproductive success, apart from confounding factors. Ruth measured mercury levels in adult tissue. Mercury should be measured in eggs of western grebes, then compared with laboratory feeding studies. Fimrite found adverse effects in pheasants occurred in range of 0.5 – 1.5 ppm mercury in eggs. Heinz found a low observable effects level of 0.86 ppm mercury in eggs of mallards. A no observable adverse effects level would be lower.**

**Ruth Elbert also measured hatching success of grebes. This is a ratio of the number of eggs hatched to the number of eggs laid. While some eggs may not hatch due to contamination, others are lost to predation, are abandoned or are infertile. A measure of hatching success does not separate likely effects of contamination from these other factors. A better measure is of hatchability, which is the ratio of number of eggs hatched to the number of eggs incubated to term. Eggs preyed upon or abandoned would not be counted in the lower term of the ratio. In most birds, normal hatchability is 90%. In a more complex study, you could select one egg randomly from a nest. Measure contaminant concentrations in the selected egg and compare with hatchability of its siblings. This type of study has been done for DDT, but not for mercury.**

**As far as tissue measurements, levels in brain tissue are best for interpreting toxicity. Brain mercury levels correlate most closely with biological effects. A good reference is the paper by Wolfe, Schwarzbach and Sulaiman (Env. Toxicol. Chem 17:146). The threshold level for adverse effects in mink is 5 ppm mercury in brain.**

We have clarified the description of Elbert's study and conclusions that can be drawn from it. The revised Report also recommends a study of hatchability be conducted with Clear Lake grebes. The review paper by Wolfe, Schwarzbach and Sulaiman has been used elsewhere in the report. We added this reference to the section on wildlife at Clear Lake.

- 3. Pg. 36, Table 9. A comment on species potentially at risk in Clear Lake. Western grebe is probably the best avian indicator species for Clear Lake. These birds feed only within Clear Lake during nesting and raising young. Taxonomically, grebes are similar to loons. I don't know if loons nest on Clear Lake. Kingfishers probably feed along streams as well as in the lake. Barr (1986) observed that reduction in egg laying and territorial fidelity by loons was associated with mean prey mercury concentrations of 0.3 ppm mercury. The last decade's research on loons has shown that Barr's toxicity threshold concentration in prey fish is correct. The dietary threshold identified in field studies is lower than that found in laboratory studies (example: the LOAEL determined in the Heinz studies of mallards was 0.5 ppm mercury in food).**

**I recommend adding western grebes and mergansers to Table 9. Body weights of western grebes and common mergansers are 1.48 kg and 1.2 kg, respectively. I calculated an acceptable fish tissue concentration for mergansers of 0.09 ppm mercury in fish wet weight; which is very similar to the safe human value.**

The calculations for western grebes and common mergansers have been added to the report. It is important to consider all of the avian species that are potentially at risk.

**4. Additional references you might want to examine:**

**Env. Toxicol. Chem 18(12)2941. A risk assessment by Moore and Sample.**

**Env Toxicol. Chem 18(9)1934 Bouton et al. This study of juvenile egrets identified an excretory pathway for mercury as their new feathers are growing. It is possible that the period of fledging after feathers are grown is a sensitive lifestage, because more mercury would be retained in tissue.**

These references have now been evaluated.

- 5. At some parts of the report, it is unclear whether the reference is to wet or dry weight. In particular, you need to be conscious of mercury concentrations in food and the amount of food eaten. Given the body weight of an individual organism, an allometric equation is used to calculate the amount of food eaten on a dry weight basis. This food consumption rate needs to be converted to wet weight.**

Much of the information on exposure factors came from the Mercury Study Report to Congress. The method for calculating and reporting of wildlife consumption rates in Table 8 of this report has been checked for uniformity. The consumption rates were presented as wet weights, which has been noted in the table.

- 6. This report and the MRC classify fish into trophic levels three and four. For a better representation of the real world, you need to work with fish size. For example, a**

**kingfisher will generally eat fish in the length range of 4-14 cm. Mink would be expected to consume fish about 20 cm or larger. An osprey will (try) to capture fish of any size. With respect to human risk, OEHHA seems most concerned about mercury levels in fish 35 cm or longer.**

Thank you for the information on fish sizes consumed that you provided here and in our subsequent phone call. I have added fish size to the table of concentrations of mercury in Clear Lake fish species. I have also discussed the calculated mercury intakes for wildlife with relationship to size and species of fish consumed.